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Articles

Economic Welfare and Food Safety Regulation: The Case of Mechanically Deboned Meat

Douglas W. McNiel

Mechanical deboning is a technology that allows red meat packers and processors to recover fragments of meat that are left on the bones of carcasses after hand trimming. The economic impact of alternative public policies, ranging from a ban on the use of mechanically deboned meat to a free market approach, is analyzed with a simultaneous equations supply-demand model of the markets for table and processed beef and pork. The results indicate that the loss in economic welfare to society, as well as the price and quantity effects associated with present restrictions, are not insignificant.

Key words: Economic welfare, food safety regulation, meat packing and processing, mechanically deboned meat, technological change.

Mechanical deboning is a technique for recovering the fragments of meat that remain on the bones of a carcass after hand trimming. In the mechanical deboning process, the bones and attached fragments of meat are ground up and fed into special deboning machines. The bone bits are screened out while the meat passes through. The result is a paste-like product called mechanically deboned meat (MDM) which, government regulations permitting, might be used as an ingredient in hot dogs, luncheon meats, and other processed meat products.

The mechanical deboning process is not new. It was developed for the Japanese seafood industry about twenty years ago and has been used in the U.S. poultry industry since 1965. More recent developments have established the technological feasibility of mechanically deboning red meats, primarily beef and pork. Red meats are being mechanically deboned now in at least twenty-nine foreign countries, including Australia, New Zealand, and Argentina. But mechanical deboning techniques have not been adopted widely by U.S. red meat processors because, until recently, U.S. Department of Agriculture (USDA) regulations never clearly defined the term "meat" to include or exclude MDM. Consequently, the associated edible red meat protein has been thrown away or sent along with the bones for inedible rendering, a low-valued use. This waste has been estimated by Field and others to amount to three to four pounds of meat per pork carcass and twelve to sixteen pounds per beef carcass.

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Proposed Regulations

The USDA began formulating a policy on the use of MDM in November 1974, when it announced a pilot program for collecting technical data on mechanical deboning procedures (USDA 1974). Cooperating red meat processors who received USDA approval were allowed to produce MDM and use it in certain formulated meat food products. In April 1976, after evaluating data from the pilot program, the USDA formally proposed regulations to expand the definition of meat to include MDM and allow MDM to be used as an ingredient in processed meat products. At the same time, the USDA issued interim regulations providing for immediate production and distribution of MDM in processed meats for human consumption (USGSA 1976).

However, a public controversy developed

over the MDM regulations. After an unsuccessful appeal to the USDA for a ban on the production and use of MDM for human consumption, several consumer-oriented groups filed a suit in U.S. District Court contending that the USDA had failed to follow proper administrative procedure in issuing the temporary regulations. The court concurred and issued a temporary injunction against implementation of the interim rules (Community Nutrition Institute et al.). Subsequently, on 14 September 1976, the USDA ordered that the official mark of federal inspection could no longer be placed on MDM. This in effect stopped domestic manufacture and distribution of mechanically deboned red meat.

Health and Safety Issues

At the court's bidding, the USDA organized a select panel of government scientists to study the health and safety aspects of the use of MDM. The wholesomeness of MDM was questioned because it contains small amounts of pulverized bone powder and because of concerns that the heat generated in the process of producing MDM might create bacterial problems. Nutritional questions about MDM concerned its calcium content (indication of bone content), the amount of fat, the amount of protein, and the quality of protein. The labeling issue concerned specification of the ingredient statement, and whether the terms "beef" and "pork" (which are designations for hand-deboned meat) are appropriate for products containing MDM, or whether labeling terminology more descriptive of the processing technique was more appropriate.

After an intensive analytical program conducted in the laboratories of the USDA's Food Safety and Quality Service and other government agencies, the select panel concluded that (*a*) bone particle size obtained with mechanical deboners currently available presents no hazards to health; (*b*) no public health problem is posed by the presence or absence in the bone of trace elements, chemical, or pesticide residues; (*c*) a slight nutritional benefit is to be expected for most people from the calcium in MDM; (*d*) the lipid spectrum of MDM is comparable to the lipid pattern found in hand-deboned meats; (*e*) the microbiology of MDM presents no unique hazards and should not be a problem if good manufacturing practices and quality control programs are employed; and (*f*) the MDM content in food products should be labeled in the ingredients statement, so that persons who must stringently restrict calcium intake can avoid these products (USDA 1977).

Final Regulations

The select panel's findings and recommendations were incorporated into a new USDA proposal published in October 1977 (USGSA 1977). After another period of public comment and revision, final MDM regulations were published 20 June 1978, and became effective one month later (USGSA 1978). Under the final regulations, MDM is classified as a meat food product rather than as a class of meat. The MDM content is limited to 20% of all meat and meat by-products used in a processed meat food product. Parameters for minimum protein quantity and quality, maximum fat and calcium content, and standards for maximum particle size, quality control, and labeling are prescribed so that "there is no basis for expecting that the long-term use of (MDM) would pose health hazards or that the long-term effects would be any different from other processed meat food products . . ." (USGSA 1978, p. 26418). Despite this conclusion, the final regulations banned the use of MDM in fresh ground beef and pork, hamburger, fabricated steaks, and other products in which USDA concluded the consumer generally expects to find whole muscle meats (USGSA 1978).

Risks, Benefits, and Regulatory Bias

The decision to prohibit the use of MDM in a large segment of the processed meat market might reflect an alleged bias of food safety regulation (Campbell, Grabowski, Peltzman, Wardell). In this instance, the nutritional, health, and safety implications of MDM use were analyzed in great detail, but little or no attention was focused in the economic impact of the regulation. The amount of edible red meat protein recoverable via mechanical deboning was not analyzed carefully nor valued properly. In fact, the USDA's final statement of MDM rules strongly implied that economic considerations were irrelevant to the regulatory decision-making process (USGSA 1978).

What the USDA regulatory process failed to take into account is that with every food safety regulatory decision come certain benefits as

well as certain costs, including risks. The goal of public policy toward food safety and quality regulation should not be to minimize health risks, but rather to determine whether a particular policy measure would result in potential benefits to society which outweigh the potential costs including attendant health risks.

Food safety regulators may have difficulty recognizing the relevance of economic analysis for implementing this simply stated objective for several reasons. First and foremost is the problem that it is often very difficult to quantify the costs, benefits, and risks associated with a particular regulation. Second, the public and their representatives are only beginning to deal explicitly with the question of what additional health risk is acceptable to obtain additional net social benefits. A recent report by a National Academy of Sciences panel recommends that Congress set up a "multi-tiered" system of food safety standards in which risks would be weighed against benefits before any regulatory decision is made to ban or restrict a substance. Meanwhile, no additional risk has been a convenient, albeit economically costly, solution for legislators and regulators. Finally, Campbell and others have suggested that this bias occurs because those who make and administer the regulations are often confronted with the task of weighing possible large risks to a few persons against relatively small benefits to many people. The significance of a large risk and its possibly devastating impact on a few individuals may be more easily comprehended and publicized than the relatively small, dispersed benefits that may accrue to many individuals. To avoid blame or risk of losing public support, food safety regulators are likely to be overly cautious.

This regulatory bias may be justifiable up to a point, because large risks are difficult to assess. However, the loss of small benefits to individuals is also important, especially when the numbers affected are large. And, as Campbell notes, while the individual's risk or cost is a "private cost which can sometimes be insured against" or recovered monetarily through legal action, "the loss sustained by never receiving a benefit is a social, noninsurable cost against which there is no legal recovery" (Campbell, pp. 22–23).

If restrictions on the use of MDM are the result of regulatory bias, economic analysis could indicate at what cost to society is the goal of no additional risk being attained. Or, if MDM in fact presents no additional health risk, economic analysis could indicate at what cost to society is the "quality range" of meat food products being restricted.

Economic Analysis

The analysis that follows is confined to the markets for beef and pork, which together account for over 96% of per capita red meat consumption (USDA, *Livestock and Meat Situation*). Red meats reach consumers in two basic final forms, as table cuts and as processed meats. The potential effects of mechanical deboning are assessed at the retail level by assuming that the inclusion of MDM in processed meat products results in a pound-for-pound increase in the supply of processed meats. This is not an unrealistic assumption because (*a*) as a processed meat ingredient, MDM is subject to little or no shrinkage; and (*b*) the regulations for utilizing MDM stipulate that it not be detectable in the final product, so final product homogeneity is maintained.

Because MDM would enter the market as an ingredient in processed meat products, adoption of the technology will have differential impacts in the markets for table and processed meats. For this reason, the markets for beef and pork must be separated into submarkets for table and processed meats.[1] This division allows a direct examination of the economic effects of mechanical deboning, because the additional meat recovered by the technique will be used as an ingredient in processed meats and will affect table cuts only indirectly. To avoid repetition, the graphical analysis below is presented generally without regard to species of meat (beef or pork). Perfectly competitive markets are assumed throughout.

Primary Effects

When mechanical deboning techniques are adopted, each carcass mechanically deboned will yield, in addition to the previous amount of table cuts, more pounds of processed meats. Figure 1 shows the demand (dd') and supply (ss') of processed meats when the use of MDM in processed meats is restricted.[2] If

[1] The term table meats, as used in this study, refers to meats which are consumed in whole muscle form, except for cutting or slicing. The term processed meats refers to meats not consumed in whole muscle form. Included are processed products in which meat ingredients are ground, flaked, extruded, or mixed with other ingredients of animal and/or vegetable origin to form a new product.

[2] The supply curves in figure 1 are positioned to reflect the price inelasticity of the linear supply curves estimated below.

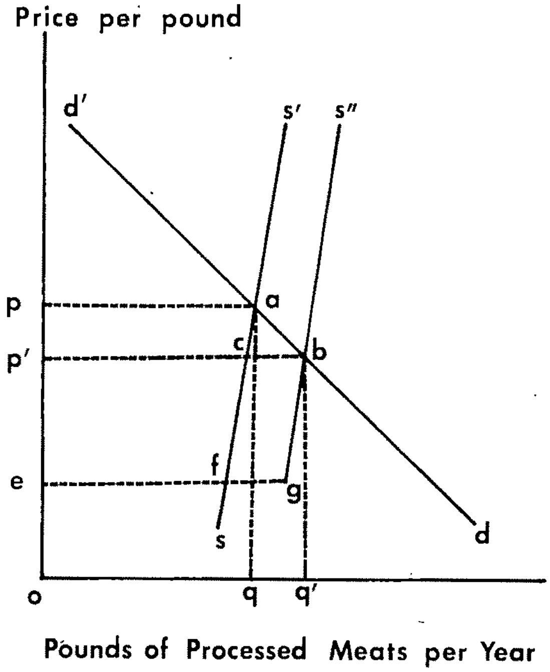

Figure 1. Demand and supply of processed meats

oe represents the minimum price at which producers find it profitable to adopt the technology, regulations relaxing restrictions on MDM use would lead to an increase in the quantity of processed meats supplied at prices above this level, but no change for lower prices. This increase in the supply of processed meats to *sfgs''* would be accompanied by a reduction in the price of processed meats from *p* to *p'*, and an increase in the quantity traded from *q* to *q'*. These price and quantity changes induced by the use of MDM in processed meats result in an increase in the economic welfare of consumers that is measured by area *p'pab*. Part of this gain to consumers is a transfer from producers whose welfare is reduced by an amount measured by area *p'pac*. This transfer from producers is at least partially offset by the welfare gain to producers measured by the area *bcfg*. The net welfare change for society (producers and consumers) is measured by area *bcfg* plus area *abc*. This area represents the net economic welfare gain to society if the use of MDM in processed meats is permitted, or conversely, the net loss in society's economic welfare if MDM use is restricted.

Secondary Effects

The secondary impact of the technology depends on the cross-price elasticities of supply and demand between table cuts and processed meats. As the price of processed meats falls relative to the price of table cuts, the demand for table cuts may decrease in the supply (technical constraints permitting) increase. While the net effect on the equilibrium quantity of table cuts is uncertain, the price of table cuts is expected to fall.

An Empirical Model

In order to estimate the sum of the small individual net benefits associated with mechanically deboning red meats, parameters of the hypothesized demand and supply relations for table and processed meats were estimated along with the appropriate own and cross-price elasticities. The demand for each type of meat was specified as a function of its own price, the prices of related goods, income, and population. The supply of each type of meat was specified as a function of its own price, the prices of related goods, the levels of inputs considered fixed for any production period, and the prices of any inputs whose level of use may be varied during the production period. The coefficients of a number of these explanatory variables were found to be not statistically different from zero, and these variables were subsequently dropped from the model.

Estimation

Series of monthly retail price-quantity data were constructed and used to estimate the parameters of the eight supply and demand equations that evolve from the theoretical analysis above.[3] Because the eight structural demand and supply equations are interdependent and each contains at least two endogenous variables, own price and quantity, the parameters of the over-identified system of equations were estimated using three-stage least squares (3SLS). The 3SLS-estimated equations, as

[3] Monthly price series for table and processed meats from 1970 to 1976 were constructed from the retail meat prices of individual retail cuts published by the Bureau of Labor Statistics and from unpublished USDA data. The prices of individual retail cuts were weighted by their market basket shares to form retail price series for table and processed beef and pork (Duewer, 1969). Monthly total civilian consumption of beef and pork was computed from figures reported in annual supplements of the USDA's *Livestock and Meat Statistics*. After conversion from carcass to retail weight basis, the data on beef and pork consumption were each disaggregated into two components, table cuts and processed meats, using share estimates obtained from USDA consumption surveys which were consistent with the market basket shares used in constructing the price series. Complete data used in this study are available in McNiel.

well as ordinary least squares (OLS) estimates obtained from preliminary investigations, are reported in table 1.

In general, the estimated results are consistent with the priori theoretical analysis developed above. All coefficients have the signs

Table 1. Estimated Equations

Demand for table beef

$$\begin{array}{lllll}
\text{OLS} & QTB = -3135.5151 & -\ 4.5118\,PTB & +\ 2.3850\,PTP & +\ .0213\,POP \quad R^2 = .59 \\
& \quad(669.8112) & (.7826) & (.5609) & (.0036) \\
& \quad{*}{*}{*} & {*}{*}{*} & {*}{*}{*} & {*}{*}{*} \\
\text{3SLS} & QTB = -5389.9361 & -\ 11.1429\,PTB & +\ 5.4511\,PTP & +\ .0351\,POP \\
& \quad(1109.6717) & (1.5325) & (.8874) & (.0061)
\end{array}$$

Demand for processed beef

$$\begin{array}{lllll}
\text{OLS} & QPB = -1164.0904 & -\ 2.8530\,PPB & +\ 1.7134\,PPP & +\ .0089\,POP \quad R^2 = .57 \\
& \quad(433.9503) & (.5429) & (.6853) & (.0023) \\
& \quad{*}{*}{*} & {*}{*}{*} & {*}{*} & {*}{*}{*} \\
\text{3SLS} & QPB = -303.6920 & -\ 4.5415\,PPB & +\ 3.7087\,PPP & +\ .0046\,POP \\
& \quad(504.2903) & (.5928) & (.7789) & (.0027)
\end{array}$$

Demand for table pork

$$\begin{array}{lllll}
\text{OLS} & QTP = 838.5997 & -\ 5.4072\,PTP & +\ 1.6061\,PPB & +\ .3832\,PI \quad R^2 = .61 \\
& \quad(47.5048) & (.5959) & (.7094) & (.0760) \\
& \quad{*}{*}{*} & {*}{*}{*} & {*}{*} & {*}{*}{*} \\
\text{3SLS} & QTP = 874.1090 & -\ 6.4472\,PTP & +\ .2950\,PPB & +\ .5553\,PI \\
& \quad(66.2273) & (.8348) & (1.1512) & (.1149)
\end{array}$$

Demand for processed pork

$$\begin{array}{lllll}
\text{OLS} & QPP = -513.1594 & -\ 2.4694\,PPP & +\ 1.0040\,PPB & +\ .0042\,POP \quad R^2 = .43 \\
& \quad(257.2542) & (.4062) & (.3218) & (.0013) \\
& \quad{*}{*} & {*}{*}{*} & {*}{*}{*} & {*}{*}{*} \\
\text{3SLS} & QPP = -1121.9326 & -\ 3.2330\,PPP & +\ .6885\,PPB & +\ .0076\,POP \\
& \quad(278.9884) & (.4313) & (.4424) & (.0015)
\end{array}$$

Supply of table beef

$$\begin{array}{lllll}
\text{OLS} & QTB = -78.6552 & +\ .1434\,PTB & +\ .2804\,CCS & +\ 4.5966\,SC \quad R^2 = .92 \\
& \quad(49.7643) & (.1347) & (.0117) & (.6916) \\
& & & {*}{*}{*} & {*}{*}{*} \\
\text{3SLS} & QTB = 28.6730 & +\ .3380\,PTB & +\ .2485\,CCS & +\ 2.9534\,SC \\
& \quad(38.2221) & (.1407) & (.0092) & (.5148)
\end{array}$$

Supply of processed beef

$$\begin{array}{lllll}
\text{OLS} & QPB = 53.7930 & +\ 1.9695\,PPB & -\ 1.2215\,PTB & +\ .1758\,CCS \quad R^2 = .93 \\
& \quad(18.0581) & (.2546) & (.1731) & (.0064) \\
& \quad{*}{*}{*} & {*}{*}{*} & {*}{*}{*} & {*}{*}{*} \\
\text{3SLS} & QPB = 27.3252 & +\ 2.5795\,PPB & -\ 1.4997\,PTB & +\ .1808\,CCS \\
& \quad(18.1884) & (.2845) & (.1821) & (.0061)
\end{array}$$

Supply of table pork

$$\begin{array}{llll}
\text{OLS} & QTP = 143.7965 & +\ .1630\,PTP & +\ .0946\,CHS \quad R^2 = .89 \\
& \quad(51.2310) & (.1822) & (.0052) \\
& \quad{*}{*}{*} & & {*}{*}{*} \\
\text{3SLS} & QTP = 92.0725 & +\ .3982\,PTP & +\ .0985\,CHS \\
& \quad(53.3948) & (.1976) & (.0052)
\end{array}$$

Supply of processed pork

$$\begin{array}{lllll}
\text{OLS} & QPP = 36.3142 & +\ .9174\,PPP & -\ .5265\,PTP & +\ .0256\,CHS \quad R^2 = .91 \\
& \quad(13.3541) & (.2041) & (.1361) & (.0014) \\
& \quad{*}{*}{*} & {*}{*}{*} & {*}{*}{*} & {*}{*}{*} \\
\text{3SLS} & QPP = 13.9843 & +\ .2805\,PPP & -\ .0321\,PTP & +\ .0291\,CHS \\
& \quad(13.5097) & (.0995) & (.0815) & (.0013)
\end{array}$$

Endogenous variables

QTB—Quantity of table beef	*PTB*—Price of table beef
QPB—Quantity of processed beef	*PPB*—Price of processed beef
QTP—Quantity of table pork	*PTP*—Price of table pork
QPP—Quantity of processed pork	*PPP*—Price of processed pork

Exogenous variables

CCS—Commercial cattle slaughter	*POP*—Population
CHS—Commercial hog slaughter	*SC*—Steer-corn price ratio, lagged one year
PI—Personal income	

Note: Standard errors are in parentheses. One asterisk implies significance at the 90% level; two, the 95% level; and three, the 99% level.

economic theory would lead us to anticipate.[4] Standard errors of the 3SLS coefficients are relatively low, except for the coefficient of the price of processed beef (*PPB*) in the demand for table pork equation, and the coefficient of the price of table pork (*PTP*) in the supply of processed pork equation. Because economic theory supports the signs of these coefficients, the variables were retained for purposes of simulating the indirect effects of alternative MDM regulations in the next section.

On the supply side of the model, cross-price effects between table and processed meat of the same species were detected only in the equations for processed beef and pork, and not in supply equations for table beef and pork. No cross-species price effects were detected in any of the estimated supply equations. This may indicate that most of the discretionary supply decisions already have been made at the farm or processing levels in an earlier time period and that the retailer's ability to alter the relative quantities in which table and processed meats of a particular species are marketed (in response to relative price changes) is limited by carcass conformation and decisions made at the processor level. On the demand side, one might expect consumers to make substitutions not only between table and processed meats of the same species, but also between species. This expectation is borne out in the estimated demand equations. The demand for processed beef, for example, is found to depend on the price of processed pork (*PPP*) as well as the price of processed beef (*PPB*). Similar cross-species price effects are found in the other three demand equations as well, but none capture all of the hypothesized cross-price effects.

Elasticities

Table 2 summarizes the retail demand and supply elasticities with respect to the price variables, calculated at the mean using the 3SLS coefficients. Both the own and cross price elasticities of demand and supply are reported when available from the estimated model.

The demand for table beef was found to be more own-price elastic than the demand for processed beef. These relative magnitudes are generally consistent with those reported by Hunt and Houck as opposed to those reported by Langemeier-Thompsons, see table 3. Comparisons of the actual magnitudes of these elasticities may be rather tenuous because of differences in the data series, time periods, and number of submarkets considered in the models from which they are estimated. In the case of pork, the relative magnitudes of the demand elasticities for table and processed pork are reversed. With the exception of Duewer's estimates for eight retail pork cuts, no comparison estimates of the elasticities of demand for table and processed pork were found in other studies.

The estimated supply elasticities are all very small. This is consistent with the fact that meat is highly perishable and has a limited

[4] The positive quantity-axis intercepts in the estimated supply equations are the necessary result for any linear supply curve which is price inelastic. As price approaches zero, the result becomes absurd. However, as the text shows, the quantity supplied at very low prices (below *oe* in fig. 1) has no effect on the analysis of welfare changes.

Table 2. Summary of Estimated Retail Demand and Supply Elasticities

	Elasticity of	
	Demand	Supply
Table beef		
Price of table beef	−1.72	.05
Price of table pork	.64	
Processed beef		
Price of processed beef	− .63	.36
Price of processed pork	.54	
Price of table beef		−.36
Table pork		
Price of table pork	− .86	.05
Price of processed beef	.03	
Processed pork		
Price of processed pork	−1.19	.10
Price of processed beef	.24	
Price of table pork		−.01

Note: Means are $QTB = 910.7$ million pounds, $QPB = 587.9$ million pounds, $QTP = 798.6$ million pounds, $QPP = 230.7$ million pounds, $PTB = 140.6¢$ per pound, $PPB = 81.7¢$ per pound, $PTP = 106.9¢$ per pound, and $PPP = 85.2¢$ per pound.

Table 3. Comparison of Selected Supply and Demand Elasticities for Table and Processed Beef

Own Price Elasticities	This Study	Hunt	Houck	Langemeier-Thompson
Table beef				
Demand	−1.72	−2.03	−1.156	− .978
Supply	.05	.156		.232
Processed beef				
Demand	− .63	−1.35	− .850	−1.243
Supply	.36	.332		− .552

shelf life. Once the livestock producer makes the decision to market the animal, the wholesaler and retailer have little short-run discretion for increasing or reducing the quantity of meat supplied in response to variations in retail prices. The relatively higher supply elasticities for processed beef and pork than for table beef and pork are consistent with the longer shelf life and less restrictive technical constraints on the production of processed meat products—table cuts can be completely converted into processed meats, in response to relative price changes, but the reverse is not technically feasible.

Policy Analysis

The equations presented in table 1 were used to simulate the price and quantity effects of alternative regulations regarding the use of MDM in processed meat products. Prices and quantities associated with a ban were compared with prices and quantities associated with two other alternative policies: the existing policy which would allow a maximum of 20% MDM as an ingredient in all processed meats except ground beef and pork, and a variant which would allow all MDM economically recoverable by existing technology to be used in processed meat products. Information on the minimum price at which the technology would be adopted (*oe* in fig. 1) was collected in a survey of eight large meat packers and processors. This price was assumed to reflect the cost of recovering MDM.

Price-Quantity Effects

The prices and quantities associated with a ban on the use of MDM for human consumption were derived directly from the model which was estimated using data that were generated when use of MDM for human consumption was banned. The prices and quantities were associated with the two alternative MDM policies were simulated by shifting the supply functions for processed beef and pork to account for the addition of MDM to the supply of processed meats. The exogenous supply shifts assumed in simulating each alternative (*fg* in fig. 1) are explained below.

The first alternative approximates the current USDA regulations in that it does not allow MDM to be used in fresh ground beef and pork. Therefore, the supplies of processed beef and pork were each shifted to the right by 20% of the amount of meat consumed in processed form, excluding ground beef and pork; on average in 1976, this implies a supply shift of 9,850 thousand pounds per month for processed beef, and 4,433 thousand pounds per month for processed pork.

The second alternative policy simulated was designed to illustrate what is feasible under a free market policy if red meat producers are allowed to utilize all the MDM they can recover economically, given the present state of the mechanical deboning technology. Industry tests reported by Field indicate that an additional eight to sixteen pounds of MDM per beef carcass and three to six pounds of MDM per pork carcass could be recovered economically, given present technology. With an assumed MDM recovery of twelve pounds per beef carcass, four pounds per pork carcass, and average annual beef and pork slaughter of 40 million head and 80 million head, respectively, processed beef supplies could be increased by 40,000 thousand pounds per month and processed pork supplies by 26,667 thousand pounds per month. These supply shifts for processed beef and pork were utilized in the free market simulation.

The monthly endogenous results from comparing these two simulations with the simulation of the conditions associated with a ban on the use of MDM in products for human consumption were exaggerated for the year 1976, and are summarized in table 4. The results indicate an increase in the quantity of processed meats traded, a decrease in the quantity of table meats traded, and lower prices for both table and processed meats. The magnitude of the price-quantity change varies considerably with the particular MDM policy simulated. The indirect effects in the markets for table beef and pork are relatively small in comparison to the direct effects in the markets for processed beef and pork. Examination of the results of these simulations confirms the a priori economic analysis of the direct effects of mechanical deboning presented above, and also provides answers to some of the theoretical uncertainties about the indirect effects of the technology.

One indication of the direct cost to society of the existing MDM regulations may be obtained by comparing the results associated with the two policies. This comparison implies that existing regulations, which prohibit the use of MDM as an ingredient in fresh ground

Table 4. Summary of Price, Quantity, and Welfare Effects Associated with Alternative MDM Regulations

Simulations for 1976 of the Change in the	Maximum Use of 20% MDM in Processed Meats, Excluding Ground Meat	Use of ALL MDM Economically Recoverable by Existing Technology
	(¢/lb.)	
Price of:		
Processed beef	−2.3	−10.7
Processed pork	−1.7	−9.7
Table beef	—[a]	−0.2
Table pork	−0.1	−0.5
	(thou. pounds)	
Quantity of:		
Processed beef	48,348	152,376
Processed pork	47,484	287,556
Table beef	−192	−888
Table pork	−480	−2,208
	($ millions)	
Welfare of:		
Consumers	224	1,110
Producers	−113	−609
Consumers and Producers	111	501

[a] Decreased by less than 0.1¢ per pound.

beef and pork, result in higher retail prices to consumers amounting to about 8¢ per pound for both processed beef and pork. This restriction also means smaller quantities of processed meats will be available to consumers: for 1976, about 104 milion fewer pounds of processed beef, and 240 million fewer pounds of processed pork.

Welfare Effects

The welfare effects attending these price and quantity changes were analyzed using the concepts of economic surplus. Following Mishan's suggestion, only the direct welfare effects in the markets for processed beef and pork are analyzed. Indirect changes in economic surplus in the markets for table beef and table pork are "simply the consequence of consumers' bettering themselves by switching from [table meats] to the new lower-priced [processed meats]" (p. 34). The linear demand and supply functions estimated above and utilized to simulate the changes in equilibrium prices and quantities associated with the alternative MDM regulations, allow the welfare effects mentioned in connection with figure 1 to be computed as follows:

Gain to Consumers
$= \text{area } p'pab = (p - p')(q + q')/2,$
Loss to Producers
$= \text{area } p'pac = (p - p')(q + q' - s(/2,$
Gain to Producers
$= \text{area } bcfg = s(p' - e)$, and
Net Change in Social Welfare
$= \text{area } abc + \text{area } bcfg = s(p + p')/2 - s(e),$

where p and q are the original price and quantity assuming MDM is banned; p' and q' are the new price and quantity under alternative simulated regulations allowing varying amounts of MDM to be incorporated in processed meats; s is the horizontal shift in the supply of processed meats associated with each of the alternative regulations; and e is the minimum price at which the technology would be adopted.

From the estimates of the changes in the economic welfare of consumers and producers reported in table 4, it is apparent that consumers stand to gain considerably from policies permitting the use of MDM as an ingredient in processed meat products. Estimates of the annual welfare gain to consumers range from $224 million to $1,110 million for 1976. While producers' welfare is reduced under each of the alternative regulations simulated, increases in the annual net economic welfare of society as a whole ranged from $111 million to $501 million or about 1% to 5% of expenditures for processed meats in 1976. The cost to society of the existing MDM regulations may be estimated by comparing the differences in the changes in economic welfare associated with the two alternative policies. This comparison suggests that the welfare loss to society from existing MDM restrictions amounts to $390 million for 1976, or about 4% of expenditures for processed meat in that year.

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References

Campbell, Rita Ricardo. *Food Safety Regulation: A Study of the Use and Limitations of Cost-Benefit Analysis.* Washington, D.C.: American Enterprise Institute for Public Policy Research, 1976.

Community Nutrition Institute et al. v. *Earl Butz.* 420 FS 751 (1976).

Currie, John M., John A. Murphy, and Andrew Schmitz. "Revised Price Spreads for Beef and Pork." *Marketing and Transportation Situation.* Washington, D.C.: USDA ERS, November, 1969, pp. 23–31.

Duewer, Lawrence A. *Price-Quantity Relationships for Selected Cuts of Pork.* Washington, D.C.: USDA AER No. 245.

Field, R. A. "Increased Animal Protein Production With Mechanical Deboners." *World Rev. Animal Prod.* 12(1976):61–73.

Grabowski, Henry G. *Drug Regulation and Innovation: Empirical Evidence and Policy Options,* pp. 13, 75–76. Washington, D.C.: American Enterprise Institute for Public Policy Research, 1976.

Houck, James P. "The Short-Run Impact of Beef Imports on U.S. Meat Prices." *Aust. J. Agr. Econ.* 18 (1974):60–72.

Hunt, R. D. "The Contrasted Effects of Quota, Autarky, and Free Trade Policies on U.S. Beef Production and Prices." Ph.D. thesis, University of Minnesota, 1972.

Langemeier, Larry, and Russell G. Thompson. "Demand, Supply, and Price Relationships for the Beef Sector, Post-World War II Period." *J. Farm Econ.* 49(1967):169–83.

McNiel, Douglas W. "The Economic Impact of Mechanically Deboning Red Meats." Ph.D. thesis, Oklahoma State University, 1977.

Mishan, E. J. *Economics for Social Decisions.* New York: Praeger Publishers, 1973.

National Academy of Sciences. *Report to Congress on Food-Safety Laws by the Expert Study Group of the Institute of Medicine and the National Research Council.* Washington, D.C., 2 Mar. 1979.

Peltzman, Sam. *Regulation of Pharmaceutical Innovation: the 1962 Amendments,* pp. 10–11, 82. Washington, D.C.: American Enterprise Institute for Public Policy Research, 1975.

U.S. Department of Agriculture. *Health and Safety Aspects of the Use of Mechanically Deboned Meat: Final Report and Recommendations, Select Panel.* Washington, D.C.: Food Safety and Quality Service, Aug. 1977.

———. *Livestock and Meat Situation.* Washington, D.C.: Econ. Res. Serv., selected issues.

———. *Livestock and Meat Statistics.* ERS Statist. Bull. No. 522, and annual supplements, 1973.

———. "Meat and Poultry Inspection Bulletin 865." Mimeographed. Washington, D.C.: Animal and Plant Health Inspection Service, 6 Nov. 1974.

U.S. Department of Labor, Bureau of Labor Statistics. *Estimated Retail Food Prices by City.* Washington, D.C., (monthly issues).

U.S. General Services Administration (USGSA). "Definitions of Meat and Classes of Meat, Permitted Uses, and Labeling Requirements." *Federal Register,* vol. 41, no. 82, 27 Apr. 1976, pp. 17535, 17560–66.

———. "Standards and Labeling Requirements for Mechanically Processed (Species) Product." *Federal Register,* vol. 43, no. 119, 20 June 1978, pp. 26416–25.

———. "Standards and Labeling Requirements for Tissue from Ground Bone." *Federal Register,* vol. 42, no. 194, 6 Oct. 1977, pp. 54437–42.

Wardell, William M., and Louis Lasagna. *Regulations and Drug Development,* p. 158. Washington, D.C.: American Enterprise Institute for Public Policy Research, 1975.

Markup Pricing in a Dynamic Model of the Food Industry

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This paper presents a dynamic model of farm and retail prices and quantities. Central to the model is the notion that increases in wholesale prices are transmitted to the retail level via markup-type pricing behavior. This behavior is shown to be consistent with firm optimization under the assumption of constant returns to scale and Leontief production technology at the retail level. The markup hypothesis is tested using the Granger-Sims causality tests. Markup-type price relationships are then estimated for twenty-two food commodities.

Key words: disequilibrium, dynamic models, marketing margins, pricing behavior.

Gardner set out the basic determinants of retail and farm level prices in a framework consisting of a six-equation model which determines (for some given commodity) the retail price and quantity, the farm price and quantity, and the price and quantity of other retail inputs (e.g., marketing services). The basic concept employed is a static equilibrium framework which assumes the equality of supply and demand in each of the three markets. This approach is an excellent vehicle of analysis, providing many interesting insights into the determinants of the farm-retail price spread. For scenarios involving time periods where inventory change is small in relation to total demand, equality of a supply and demand is a realistic assumption. Given the presence of auction markets at farm levels and price competition at retail levels, agricultural markets clear quickly and this assumption is often valid. However, as the time period under consideration becomes shorter, disequilibrium becomes more of a factor in these markets. At the heart of the disequilibrium notion is the recognition that time is required for markets to clear. Hence, while being useful for analyzing the determinants of equilibrium values of the endogenous variables, the Gardner analysis has little to say concerning the time path from one equilibrium point to another. The purpose of this paper is to put forth a theory of food price determination which is consistent with the static model, but which goes beyond it and attempts to describe the dynamics of the sector.

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A Theory of Food Price Determination

The theory of price determination outlined here includes retail, wholesale, and farm levels. Letting uppercase letters represent quantities and lowercase letters represent their respective prices, the retail demand for any given food item is

$$R^d = h_1(r, y),$$

where R^d is retail quantity demanded, r is retail price, and y represents (exogenous) factors such as income. The retail supply function, which is the reduced form of the maximized production function, is

$$R^s = h_2(r, w, z),$$

where R^s is quantity supplied, w is the wholesale price, and z represents prices of other (exogenous) factor inputs, such as marketing services. Demand at the wholesale level for the food input is a derived demand from the retailer and is one of the set of factor demands which result from the derivation of the supply curve. Symbolically this relation is

$$W^d = h_3(r, w, z),$$

where W^d is the quantity demanded at the

wholesale level (e.g., beef carcasses). The supply by the wholesaler is

$$W^s = h_4(w, f, x),$$

where f is the farm price and x is other wholesaler costs. The demand by the wholesaler for the farm input is

$$F^d = h_5(w, f, x).$$

The demand-supply block of the model is closed by specifying the supply of farm input as

$$F^s = h_6(f).$$

The above model is similar to Gardner's, with the exceptions that the wholesale level has been added and there are no demand and supply relations for other factor inputs. It differs from Gardner's model in that it does not assume the equality of supply and demand in both product and factor markets, i.e., $R^d \neq R^s$, $W^d \neq W^s$, and $F^d \neq F^s$. Observation of inventory levels for many agricultural markets indicates that supply and demand are not continually in balance. Recognition of this imbalance has led researchers (Samuelson, pp. 260–69) to specify price adjustment equations following the excess demand approach, or

$$\begin{aligned} r &= h_7(R^d - R^s), \\ w &= h_8(W^d - W^s), \text{ and} \\ f &= h_9(F^d - F^s). \end{aligned}$$

Specification of the above relations serves to "close" the model in terms of equality of equations and unknowns.[1] However, for some levels of the food distribution system, excess demand relationships such as the above seem inappropriate. This is especially true of the retail level. First, there exists no marketwide agent, such as an auctioneer, to initiate the price changes required to drive the unintended inventory change ($R^d - R^s$) toward zero. Second, given the array of products marketed in a modern supermarket, merely keeping track of inventory of each item for restocking purposes appears to be a substantial task. An operationally more realistic theory is one where store managers apply a markup over costs for each product in order to arrive at a price. This notion of markup pricing is reasonable when viewed from the point of view of a store manager. Price changes at the next stage below may be thought of as "signals" which other managers also receive.[2] Hence, the chance of miscalculating and being the only agent to change price in a different manner is reduced, since all managers receive the same signal. This approach is also consistent with economic theory. First begin by noting that under the assumption of constant returns to scale (assumed also by Gardner) the firm's cost function

$$C = h_{10}(R^s, w, z)$$

can be written as

$$C = h_{10}(w, z)R^s.$$

Hence, marginal cost

$$\frac{\partial C}{\partial R} = h_{10}(w, z),$$

which under competitive conditions equals price, or

$$r = h_{10}(w, z). \tag{1}$$

In the short run, food retailing is perhaps best characterized as requiring constant amounts of each input to produce a unit of output. For each unit of output, inputs are required in "fixed proportions." The production function underlying this notion is the well-known input-output or Leontief production function (see Diewert), which for the food retailer can be written as

$$R = \min\left(\frac{W}{a_1}, \frac{Z}{a_2}\right), \tag{2}$$

which has (for constant returns to scale)

$$C = (a_1w + a_2z)R$$

as a cost function. Hence, under competitive conditions,

$$r = a_1w + a_2z. \tag{3}$$

The associated input demand functions are

$$\begin{aligned} W &= a_1R, \text{ and} \\ Z &= a_2R. \end{aligned}$$

For short-run analysis, when the firm is unable to adjust its fixed technology to changing factor prices, the above analysis is applicable. This would appear to be a realistic description of the retail food store's technology at any given time. The Leontief model implies that the elasticity of substitution (σ) between W

[1] Considerations of other components of demand such as inventory holdings and export demand are intentionally omitted in order to focus on the dynamic price formation relations.

[2] Hence the term "stage of processing" model. For more on this, see Popkin.

and Z is zero. In the long run, when inputs are allowed to vary, this assumption is unrealistic. Various substitutions occur as stores become more capital intensive, products are packaged differently, etc. A nonzero, but constant, elasticity of substitution between inputs can be modeled with the constant elasticity of substitution (CES) production function,

$$R = \gamma[\beta W^{-\rho} + (1 - \beta)Z^{-\rho}]^{-\frac{1}{\rho}},$$

which yields the price function,

$$r = \{(\beta/w)^{\sigma}w + [(1 - \beta)/z]^{\sigma}z\}^{\frac{1}{\sigma}},$$

and input demand functions

$$W = g_1\left(\frac{r}{w}\right)^{\sigma}R, \text{ and}$$

$$Z = g_2\left(\frac{r}{z}\right)^{\sigma}R,$$

where $\sigma = \dfrac{1}{1 + \rho}$, $g_1 = \gamma^{-\rho}\beta$, and $g_2 = \gamma^{-\rho}$ $(1 - \beta)$. Assuming that the Leontief technology is "set in place" at some past time (denoted by o), (3) becomes

$$r = a_{1o}w + a_{2o}z, \text{ where}$$

$$a_{1o} = g_1\left(\frac{r_o}{w_o}\right)^{\sigma} \text{and } a_{2o} = g_2\left(\frac{r_o}{z_o}\right)^{\sigma}.$$

If it is assumed that σ is relatively low, then $\left(\dfrac{r_o}{w_o}\right)^{\sigma} \simeq 1$ and $\left(\dfrac{r_o}{z_o}\right)^{\sigma} \simeq 1$. Hence,

$$r \simeq g_1w + g_2z = \left(\frac{\beta}{\gamma}\right)w \quad w + \frac{(1 - \beta)}{\gamma}z.$$

It should be noted that relationships such as (3) could be a result (in an *ex post* accounting sense) as opposed to a behavioral relationship in the model just described. For example, if all markets cleared instantaneously (i.e., if $R^s = R^d$, $W^s = W^d$, and $F^s = F^d$—the Gardner case) and if the production technology were described by (2), then prices will be given by (3) identically. What remains to be done now is to describe how relations such as (3) may be employed as a consistent pricing rule in a disequilibrium model where time is required to make adjustments.

The first step in the development of such a model is the recognition that (1), or for the specific fixed proportions example, (3), is in fact the supply relationship. Under constant returns to scale, marginal cost is a constant over all ranges of output. That (1) is the supply curve can be seen by considering the nonconstant returns-to-scale case. For a Leontief cost function with returns to scale equal to v,

$$C = (a_1w + a_2z)R^v,$$

we have

$$\frac{\partial C}{\partial R} = v(a_1w + a_2z)R^{v-1} = r.$$

The resulting supply curve is

(4) $$R^s = [r(a_1w + a_2z)^{-1}]^{(v-1)^{-1}}.$$

If $v = 1$, (3) results. Hence, rather than setting the supply of output, as they would under (4), firms with CRTS set price.

Given that (3) is an optimal pricing policy for firms with a Leontief technology and CRTS, how should a market model incorporating disequilibrium be closed? The answer lies in the treatment of inventory policy. Consider the following simplified two-level market model where production at the retail level is governed by[3]

$$R = \min\left(\frac{F}{a_1}, \frac{Z}{a_2}\right), \text{ and, therefore,}$$

(5) $$r_t = a_1f_t + a_2z_t,\text{[4] and}$$

(6) $$F_t^d = a_1R_t^s \qquad a_1 > 0.$$

Retail demand is given by

(7) $$R_t^d = \alpha_o + \alpha_1r_t \qquad a_1 < 0,$$

and farm level supply is

(8) $$F_t^s = \gamma_0 + \gamma_1f_t \qquad \gamma_1 > 0.\text{[5]}$$

Prices at the farm level are instantaneously determined by excess demand,

(9) $$\Delta f_t = \beta_o(F_t^d - F_t^s) \qquad \beta_o > 0.$$

With retail price given by (5), the remaining variable to be controlled by the retailer is the quantity supplied in period t, or R_t^s. Since demand may shift (a change in α_o), the firm cannot predict demand with certainty. One useful rule is to set the current period's supply equal to the last period's demand, or

[3] The wholesale level has been deleted for ease of exposition.

[4] We note in passing that for many agricultural commodities, $a_1 \simeq 1.0$. Hence, the elasticity of retail prices with respect to farm price is f/r or the farm-retail price ratio. The a_i's are actually the physical units of farm product needed to produce one retail unit of the product. These requirements are in fact the much-publicized farm equivalents. See Brandow.

[5] For some livestock products it has been shown that $\gamma_1 < 0$ in the short run. However, this occurs when f is an expectational variable—a situation not treated here.

(10) $$R_t^s = R_{t-1}^d.$$

This rule has definite implications for inventory policy. The market described by this model operates in the following manner. Given some shift in demand at retail level, inventories will be depleted more than expected, but retail and farm price will remain unchanged. At the start of the next period, inventories will be increased through the rule given by (10). This increase in R^s will be transmitted to the farm level through (6), and farm and then retail prices will increase in view of (9) and (5). The increase in retail price will tend to restrict retail demand, setting the scene for a downward adjustment of R^s in the next period. This process will continue for several periods until prices and quantities reach their new equilibrium values—assuming that the solution is stable. In order to test the stability of the above model, begin by noting that the six-equation model given by (5)–(10) can be reduced to a simultaneous system of second-order difference equations,

(11) $$r_t = a_1k_o + a_1k_1r_{t-1} + a_1k_2f_{t-1} + a_2z_t, \text{ and}$$

(12) $$f_t = k_o + k_1r_{t-1} + k_2f_{t-1}, \text{ where}$$

(13) $$k_o = (\beta_oa_1\alpha_o - \beta_o\gamma_o)k_2,$$

(14) $$k_1 = (\beta_o\alpha_1a_1)k_2, \text{ and}$$

(15) $$k_2 = (1 + \beta_o\gamma_1)^{-1}.$$

The solution will be stable if the modulus of the characteristic equation of (11) and (12), given by

(16) $$\lambda^2 + \lambda(-k_1a_1 - k_2) = 0$$

lies in the unit circle. The two roots of (16) are

$$\lambda_1 = 0$$
$$\lambda_2 = k_1a_1 + k_2.$$

Using (14) and (15),

(17) $$\lambda_2 = (1 + a_1^2\beta_o\alpha_1)(1 + \beta_o\gamma_1) < 1$$

for the parameter restrictions given above. Hence, the system will be stable if $\lambda_2 > -1$. An exact statement is not possible. However, writing (17) as

$$\lambda_2 = \left(\frac{1}{\beta_o} + a_1^2\alpha_1\right)\left(\frac{1}{\beta_o} + \gamma_1\right)^{-1},$$

it can be shown that if $\left|\frac{1}{\beta_o}\right| > a_1^2\alpha_1$ and $\left|\frac{1}{\beta_o}\right| > \gamma_1$, $\lambda_2 > -1$. Intuition suggests that $\frac{1}{\beta_o}$ will be large relative to $a_1^2\alpha_1$ and γ_1. Hence, the model can give rise to both damped and explosive oscillatory growth as well as convergent growth. Only divergent growth is ruled out. The model is more general in this sense than the classic Cobweb model which permits only damped and explosive oscillatory behavior. However, the main point of the above exercise is to demonstrate that the model given by (5)–(10) can give rise to stable solutions and that for these stable solutions the optimal pricing rule given by (5) will hold. The remainder of the paper is devoted to an empirical test of one component of the above theory—the markup pricing rule given by (3). This is not meant to imply that the other behavioral relations are not important. However, extensive empirical analyses have been undertaken on retail food demand and farm supply. While empirical tests of the inventory rule would be desirable, it is not clear that the available data will support such a test.

Before passing on to the tests, it should be noted that the above analysis is useful in interpreting several results derived by Gardner with respect to markup pricing. First, it can be shown that all CRTS production functions will yield price relationships of the form

$$r = b_1f + b_2z, \text{ where}$$
$$b_1 = h_{10}^f(f, z), \text{ and}$$
$$b_2 = h_{10}^z(f, z).$$

The above can be proved easily. First, remembering that for CRTS

(18) $$C = h_{10}(R, f, z) = h_{10}(f, z)R.$$

Because the definition of the cost function is

$$C = Ff + Zz,$$

and from Shephard's lemma (Diewert, pp. 495–96),

$$F = \frac{\partial C}{\partial f}, \text{ and}$$

$$Z = \frac{\partial C}{\partial z},$$

(18) can be written as

$$C = [fh_{10}^f(f, z) + zh_{10}^z(f, z)]R.$$

Hence,

$$\frac{\partial C}{\partial R} = r = b_1f + b_2z, \text{ where}$$

$$b_1 = h_{10}^f(f, z), \text{ and}$$
$$b_2 = h_{10}^z(f, z).$$

For dynamic models where b_1 and b_2 are "set in place" by past prices, pricing rules will be of the fixed markup variety at any given point in time, regardless of the *ex ante* production function. Hence, markup pricing will yield fully consistent results in a theoretical sense for dynamic models with CRTS and (at any given time) fixed technology. Second, Gardner makes the point that "no simple markup pricing rule . . . can in general accurately depict the relationship between farm and retail price" (Gardner, p. 406). The validity of this statement is a direct result of the fact that b_1 and b_2 above are endogenous to the Gardner model and will change differentially depending on how f and z change as a result of various shifts in their basic determinants. This result shows at once the strengths and weaknesses of a static model. To allow changes in technology (as a result of basic supply and demand shifts) to explain changes in margins and price transmission is an extremely valuable tool. When employing this tool, it must be borne in mind that one is considering a time period long enough for these price-induced technological changes to occur.[6] Hence, the stability of the coefficients in (3) can provide clues as to the proper period of time for use of a static model.

Testing for Causal Direction

The general model presented above relies on the notion that changes in prices at the retail level are caused by changes in prices at the wholesale level. For some commodities, this notion could also be extended to the farm-wholesale stage. However, problems in obtaining independent farm and wholesale price measures for highly integrated industries such as poultry and eggs and processed vegetables, extreme seasonality, and the presence of speculative inventory behavior require that a detailed, industry-by-industry analysis be conducted to test the price markup model at the wholesale level. At the retail level this behavior is much more plausible mainly for the reasons given above. The notion of one buyer (the retail outlet) for all commodities, the ability of that buyer to set price (i.e., absence of auction markets), and the myriad of products to be priced lend credence to the rule. Hence, tests will be conducted at the retail stage only for the model given by (3), which in effect says that wholesale prices and other input prices cause retail prices.

The notion of causality has long plagued empirical economic analysis. Problems of "mutual trends" or third factor causality have made econometricians reluctant to draw causal conclusions based on regression results. Some attempts have been made to "detrend" the data or deal in percentage changes, but in the main, the question of causality is decided a priori, based on theoretical considerations. Given the nonexperimental manner in which economic data are obtained and the aforementioned problems with time-series data, this theoretical approach is justified. Recently, Sims, utilizing a concept of causality from time-series analysis developed by Granger, has devised a method to test for causal direction.[7] The test proceeds by first filtering the series.[8] The filtered values of the original series, X and Y, are referred to as $\bar{X}$ and $\bar{Y}$. A regression, of the form

$$\begin{aligned}\bar{Y} = \beta_0 + \beta_1\bar{X}_{t+4} + \ldots + \beta_4\bar{X}_{t+1} \\ + \beta_5\bar{X}_t + \beta_6\bar{X}_{t-1} + \ldots + \beta_{13}\bar{X}_{t-8} \\ + \beta_{14}D_1 + \ldots + \beta_{24}D_{11} + \beta_{25}t + u_t,\end{aligned}$$

is performed where the D's represent monthly seasonal dummies. The coefficients $\beta_1, \ldots, \beta_4$ are called future coefficients. Significance tests are then made on the future coefficients from each regression. Table 1 summarizes the various possible combinations and the implications of each. The results of applying the causality tests to monthly data from 1960-1 to 1976-12 for twenty-three food items are summarized in table 2.

Table 1. Conditions for Direction of Causality

Regression	Future Coefficients	Direction
$\bar{Y}$ on $\bar{X}$	Significant	Unidirectional
$\bar{X}$ on $\bar{Y}$	Not Significant	from Y to X
$\bar{Y}$ on $\bar{X}$	Not Significant	Unidirectional
$\bar{X}$ on $\bar{Y}$	Significant	from X to Y
$\bar{Y}$ on $\bar{X}$	Significant	Bidirectional
$\bar{X}$ on $\bar{Y}$	Significant	between X and Y
$\bar{Y}$ on $\bar{X}$	Not Significant	Independence
$\bar{X}$ on $\bar{Y}$	Not Significant	between X and Y

[6] This is in no way meant to imply that Gardner was not fully aware of this requirement.

[7] In actuality there are several tests based on the Granger notion. These tests are discussed fully in Feige and Pearce. The tests employed here follow Sims.

[8] The filter weights used for this study were $\bar{Y}_t = \ln Y_t - 1.51 \ln Y_{t-1} + .562 \ln Y_{t-2}$. The first difference filter $\bar{Y}_t = \ln Y_t - \ln Y_{t-1}$ was also used. The results were invariant.

Table 2. Classification of Test Results

Condition	Wholesale-Retail
Unidirectional-upward	beef, oranges, frozen orange juice, rice, salad oil, margarine, vegetable shortening, sugar, pork, potatoes, frozen french fries, bread, chocolate bars (57%)
Unidirectional-downward	milk, soft drinks (9%)
Bidirectional-causality	butter, fresh orange juice, canned tomatoes (13%)
Independence	broilers, eggs, apples, tomatoes, lettuce (21%)

Note: Significance tests were based on t-values of 1.5 or greater, which for this sample size correspond to a 94% confidence interval. The percentage figures in parentheses represent the proportion of the total number of commodities in each class.

With the exception of soft drinks and chocolate bars, the food items in table 2 were selected from the U.S. Department of Agriculture (USDA) market basket. The retail prices are USDA data while the wholesale price indexes are from the Bureau of Labor Statistics. Broadly speaking, the results in table 2 support the theoretical arguments given above concerning the direction of causality from wholesale to retail. There are, however, important exceptions. The proportion of items displaying independence is larger than would be expected. However, this is consistent with recent findings by Pierce in an extensive examination of monetary variables. Pierce ascribed the large degree of independence mainly to lack of sufficient variability in the data or lack of controlled experimentation. Also, the existence of control strategies such as price supports tends to obscure the lag distribution pattern. In interpreting the above results, the reader should be cautioned that considerable controversy surrounds these causality tests. These problems center around two areas: the choice of a filter and the choice of the test itself. As noted above, several alternative testing procedures exist as empirical implementations of the Granger definition. Tests by Feige and Pearce using all three tests on the money-income hypothesis found the results sensitive to both the test procedure and to the filter used. Choice of a proper filter has long plagued spectral analysis and the same appears true for these tests. Nonetheless, the results are in accord with the theoretical development above in section 1 and on that basis tend to reinforce those considerations.

Wholesale-Retail Price Relationships

The notion of the price linkage between the wholesale and retail levels has thus far been confined to the specification given by (3). However, our empirical tests are based on monthly data and hence, for reasons given below, it may be useful to specify retail prices as a distributed lag in wholesale prices, or

$$(19)\quad r_t = \beta_0 + \beta_1 w_t + \ldots + \beta_k w_{t-k} + \beta_1 ulc_t + \beta_m ur_t,$$

where r is retail price, w is wholesale price, ulc is unit labor costs for retail food stores, and ur is the unemployment rate.[9] The distributed lag in w is specified to account for the notion that store managers may wish to use a "smoothed" value of w to avoid changing prices. Changing price is not a problem for perishables, but for items with a long shelf life, price changing is costly both in terms of time to put on new labels and in goodwill lost. Also, it may be true for some items that data collection times differ. Hence, for example, the January beef prices will represent prices observed at different days in the month. Unit labor costs, instead of the wage rate, were used for similar reasons. Unit labor cost data displayed a smoother time path than wage rates and in order to conserve degrees of freedom, ulc was used as opposed to a distributed lag in wage rates.[10] Also included was the unemployment rate as a measure of firms' normal unit rate of return. The results of fitting the model given by (19) to monthly data for the twenty-two commodities are given in appendix A. The relations typically displayed considerable autocorrelation. A correlation was made using Durbin's method. The results of appendix A are self-evident, with the exception of column (10)—the asymmetry test. The asymmetry hypothesis tests whether retailers treat increases in wholesale prices in a manner differ-

[9] Although the fixed coefficient theory does not indicate a constant term (β_0), one is included due to problems in estimating regressions without intercepts. On this problem see Gillingham and Heien.

[10] Wage rates, in fact, dominate the movement in unit labor costs for retail stores. Regressions were run with wage rates and the results were quite similar. Also, regressions with a six-month moving average of wage rate and unit labor costs showed virtually no difference.

ent than decreases. More precisely, it is often hypothesized that increases in prices are passed on fully, while decreases are not, mainly so that other costs (wages) can be "worked in." Fortunately, the methodology for testing such a hypothesis has been fully developed. In a study of supply response, Tweeten and Quance estimated an irreversible supply relation (i.e., a supply with asymmetrical price response) using dummy variables. In subsequent notes, Wolffram and Houck pointed out that their approach was unduly restrictive in that only the slopes and not the intercepts were allowed to be different. In order to implement this test at the retail level, two new variables (w_1 and w_2), representing upward and downward movements in the wholesale price, respectively, were computed. A regression of the form

$$r = \beta_0 + \beta_1 w_1 + \beta_2 w_2 + \beta_3 ulc + \beta_4 ur$$

was performed. The coefficient β_1 gives the effect on retail prices when wholesale prices are rising, while β_2 measures the effect when wholesale prices are falling. The hypothesis to be tested then reduces to the equality of $\hat{\beta}_1$ and $\hat{\beta}_2$, or H: $\hat{\beta}_1 - \hat{\beta}_2 = 0$. The statistic for this t-test is found in the lower half of column (10). Examination of column (10) shows that in twelve of the twenty-two cases, the sign was positive. Although $(\beta_1 - \beta_2)$ should be greater than zero if the hypothesis holds, a simple examination of signs indicates it does not. Rejection of the hypothesis is further reinforced by the fact that in only five cases does the t-value have both the correct sign and exceed two standard errors. A structural stability test was performed on each relation to determine whether or not there was a significant change in coefficient values in the 1975-1 to 1976-12 period. Using a test value of 4.0, the hypothesis of structural change was rejected in fifteen out of twenty-two cases. The stability of these parameters lends support to the Leontief-fixed proportions technology concept specified above.

Summary

This paper presents a dynamic theory of food price determination for the farm, wholesale, and retail sectors. The system derives its dynamics from the assumption that supply and demand are not in balance and that this imbalance is the determining factor in causing price changes in auction-type markets. Central to this theory is the notion that changes in retail food prices are caused by changes in prices at lower levels in the marketing chain. These cost changes are transmitted via markup-type-pricing rules which are shown to be consistent with firm optimization behavior under the assumption of constant returns to scale and time-fixity of production coefficients. Solution properties of the model allow for convergent growth and damped and explosive cycles, ruling out only divergent growth. For reasonable parameter values, solutions are stable and convergent growth appears to be the most likely case. The hypothesis of markup pricing at the retail level is tested by applying the Granger-Sims causality tests. Test results show that for the majority of the twenty-two commodities tested, unidirectional causality from wholesale to retail is the rule. Next, empirical price markup relations are estimated using retail price as a distributed lag in wholesale prices and unit labor costs. Additional tests on structural stability and asymmetric pricing are also performed. The relations are structurally stable and the hypothesis of asymmetric pricing behavior is rejected.

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References

Brandow, G. *Cost Components of Farm Retail Price Spreads for Foods*. Washington, D.C.: National Commission on Food Marketing Tech. Stud. No. 9, June 1966.

Diewert, W. E. "An Application of the Shephard Duality Theorem: A Generalized Leontief Production Function." *J. Polit. Econ.* 79(1971):481–507.

Durbin, J. "Estimation of Parameters in Time-Series Regression Models." *J. Royal Statist. Soc.* Series B, vol. 22, pp. 129–53, 1960.

Feige, E. L., and D. K. Pearce. "The Casual Causal Relationship between Money and Income: Some Caveats for Time Series Analysis." Social Systems Research Institute, University of Wisconsin, Workshop Series 7809, July 1978.

Gardner, B. L. "The Farm-Retail Price Spread." *Amer. J. Agr. Econ.* 57(1975):399–409.

Gillingham, R. F., and D. M. Heien. "Regression Thru the Origin." *Amer. Statistician* no. 1 (1971), pp. 54–55.

Granger, C. W. "Investigating Causal Relations by Econometric Models and Cross-Spectral Methods." *Econometrica* 37(1969):424–38.

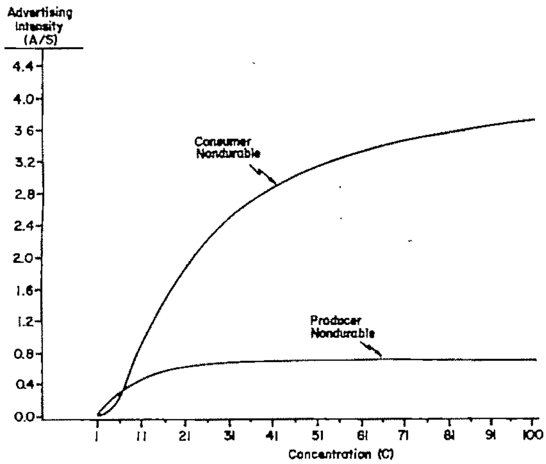

Figure 1. Advertising intensity-concentration relationship for consumer and producer nondurables (1967)

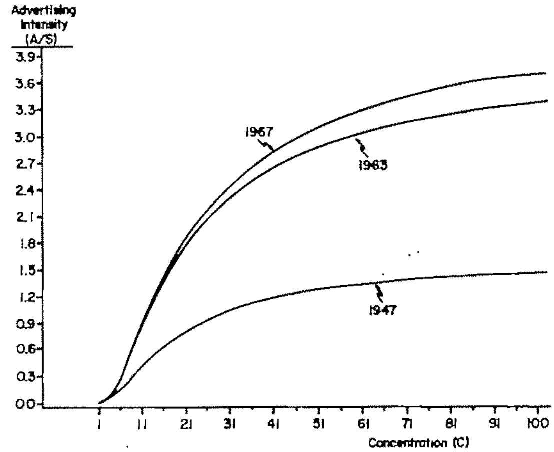

Figure 2. Advertising intensity-concentration relationship for consumer nondurables across time (1947, 1963, 1967)

creases, the advertisng intensity rises rapidly for both goods. Beyond the 20% level very little increase among producer goods industries is evident; whereas, advertising continues to rise rapidly for the consumer goods. The durable category is not shown since the relationship does not differ significantly from that shown in figure 1.

Adjustment over Time

Figure 2 illustrates the adjustments that have taken place since 1947, and the increased use of advertising for each concentration level is most apparent. Advertising intensity has increased and one important consideration is how much increase would have occurred without any change in concentration. Increased intensity with more concentration suggests substitution of nonprice for price competition. Increased intensity over time holding concentration levels fixed does not preclude the substitution for price competition, but it does indicate that greater effort to establish information flows has occurred.

The changing slopes of each response in figure 2 is of special importance in that they clearly show that the effects of structural change on advertising intensity have increased since 1947. The rate of increase in advertising intensity to increases in concentration nearly doubled between 1947–67. While advertising has become more important to concentrated industries, the results still do not totally show how much of this change represented substitution for price competition. A useful extension of the analysis would be to explore an index of price changes among the same industries included in this study.

Figure 3 is useful for depicting the adjustment that has occurred since 1947, holding all concentration levels fixed at their 1947 values. The vertical axis gives the estimated percentage adjustments that would have occurred due to the time alone and is calculated as

$$(3) \quad \frac{(A/S)_{67}}{(A/S)_{47}} - 1 = \exp^{-\left\{\beta_3 + \frac{\alpha_2}{C_{47}}\right\}} - 1,$$

where $C_{47} = C_{67}$ is assumed [see eq. (1)].

Advertising intensity would have declined over time for those industries with concentration under 2%. Whereas for industries having initial concen-

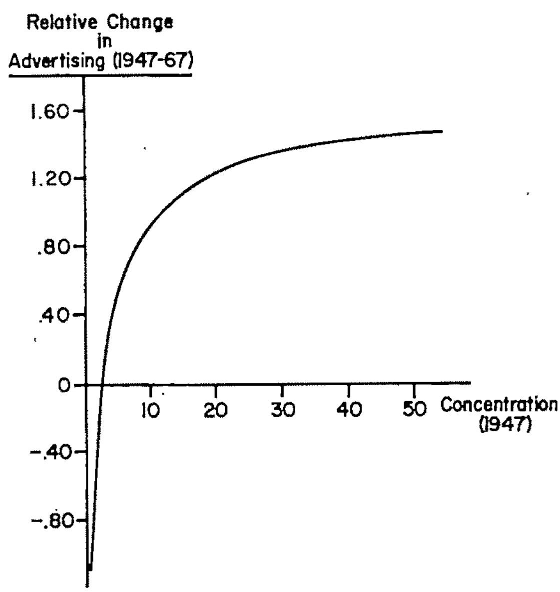

Figure 3. Relative change in advertising intensity from 1947 to 1967 holding concentration levels fixed (see eq. 3)

turing (Ornstein, pp. 74–85). Industries differ within the four-digit classification and, hence, the effect of concentration may vary across industries. Therefore, in addition to the classifications by type and perishability, the concentration parameter may have a random component giving $\alpha_0 + \nu$, where ν is an error term having the traditional properties. The dummy variables were defined such that both β_0 and α_0 represent some average effect, and the differences in type are calculated as some adjustment to this average. The randomness in the concentration coefficient is calculated only for this average and not each parameter in (1). The error in (1) is now $\mu + \nu(1/C)$, and the variance is $\sigma_\mu^2(1 + \rho/C^2)$, letting $\rho = \sigma_\nu^2/\sigma_\mu^2$ (Maddala, p. 390).

Equation (1) is estimated by maximizing the concentration likelihood function over values of ρ and the results are shown in table 2. The random coefficient model adds little to the analysis since the maximum value of the likelihood function occurs when $\rho = 0$. Pooling the data across four-digit concentration levels after explicitly accounting for time, type, and perishability does not create estimation problems that might have been expected initially, given the diverse nature of the industries included in the sample.

The statistical results shown in table 2 are probably the strongest to date in support of the relationship between advertising intensity and concentration. The t-values for α_0 and α_1 show the relationship to be significant at the 99% confidence level. Furthermore, response among consumer industries is statistically different from those producer goods industries. This difference is of particular interest since much of agricultural manufacturing relates to consumer goods in the form of food and kindred products. No statistical difference between durable and nondurable goods is evident. Finally the coefficient of determination shows that 39% of the

Table 2. ML Estimates of the Advertising-Concentration Relationship with ρ = 0.

		Parameter Estimates	t-Statistic
Intercept	β_0	.47938	4.4040
PRO	β_1	.94502	13.1690
DUR	β_2	.05811	.8742
T_1	β_3	−.95036	−6.6267
T_2	β_4	−.10597	− .8016
$1/C$	α_0	−10.20310	−4.0863
PRO/C	α_1	−7.14310	−4.1137
DUR/C	α_2	−1.14322	−0.7183
T_1/C	α_3	2.82010	.8711
T_2/C	α_4	1.51140	.5678
		R^2	= .3982
		$F(9,904)$	= 59.82
		OBS	= 914

Note: The model is estimated as a log-reciprocal equation with the dependent variable A/S (see eq. 1). The concentrated likelihood function was maximized when $\rho = 0$.

variation in advertising intensity has been explained. Other factors, some of which are likely unique to each industry, must be addressed in order to further explain intensity. What is important at this stage in the advertising-concentration dialogue is that the relationship has been established. An alternative to model (1), where substantial concentration could eventually lead to less advertising, has been specified as

$$(2) \qquad \frac{A}{S} = \exp^{(\tau_0+\tau_1/C+\mu)}C^{\tau_2}.$$

If $\tau_2 < 0$ and $\tau_1 < 0$, advertising intensity could both increase and decrease with C. This function has the property that $A/S \geq 0$, whereas many of the polynomial functions reported could yield $A/S < 0$. This model was estimated and the empirical results failed to yield any improvements over those in table 2, thus adding more credence to the asymptotic function (Ornstein, Strickland and Weiss).

Product Classifications

As suggested above, a large number of the nondurable industries relate to food and kindred industries. Attempts, however, explicitly to separate out the advertising intensity relationship for this subset of four-digit industries have not proven significant. Rather, the broad product class of consumer versus producer goods is the most important distinction. This would be expected because buyers of producer goods should be less susceptible to product image created by advertising (Mann, p. 139; Strickland and Weiss, p. 1111). Producer products are purchased in sufficient volume and frequency that the alternatives can be appraised. Also, consumer goods are generally more differentiable. Generally, the number of potential buyers are less for the producer versus consumer goods and, hence, the cost of reaching the buyers of producer goods should be less.

When comparing the effects of concentration on consumer versus producer goods, one would expect intuitively the elasticity of demand to change less among those producer versus consumer goods because the product is judged primarily on its characteristics and less on image. Hence, the significance of α_1 in table 2 seems plausible from a theoretical perspective. We are still left with the issue of what happens to ϵ_a for both product categories. If consumers are more susceptible to the image effect in consumer goods as suggested by Mann, then $\partial\epsilon_a/\partial C$ for consumer goods is likely to exceed that of producer goods and the advertising intensity for consumer goods should exceed that of producer goods.

The relationship between producer and consumer goods is illustrated in figure 1 for the nondurable category. Obviously, advertising plays a small role in the very low concentrated industries regardless of the product category. As concentration in-

Table 1. Hypothesized Effects of Concentration on Advertising Intensity [$\partial(A/S)/\partial C$]

	$\partial\epsilon_a/\partial C$		
$\partial\lvert\epsilon_d\rvert/\partial C$	+	0	–
+	?	–	–
0	+	0	–
–	+	+	?

Note: The signs within the table follow from the relationship where $\partial(A/S)/\partial C = (1/\lvert\epsilon_d\rvert)[\partial\epsilon_a/\partial C - (A/S)(\partial\lvert\epsilon_d\rvert/\partial C)]$, as derived using the Dorfman-Steiner theorem.

The problem with hypothesizing the advertising-concentration relationship is illustrated in table 1, where the alternative signs for $\partial(A/S)/\partial C$ are shown. Given the difficulties in determining the signs from the effects of concentration on ϵ_a and ϵ_d, an alternative would be to estimate directly the relationship between advertising and concentration. The empirical results may then suggest the relative importance of ϵ_a and ϵ_d to the advertising-concentration issue.

Advertising-Concentration Model

The analysis from the above section indicates that the advertising-concentration relationship ultimately will depend on empirical models. To date, mixed results have been reported when estimating the model where $A/S = f(C)$ (Mann, pp. 142–56). While the theoretical problems cannot be compromised, many of the difficulties with previous studies can be related to model misspecification, incompleteness in data classification, and inappropriateness of the estimation techniques. Recent studies by Ornstein have addressed the empirical problems of relating advertising and concentration. His studies show a positive but statistically weak relationship between concentration and advertising. Additional studies by Brush provide support for the validity of the data series developed by Ornstein.

For the present problem, concentration and advertising data are taken from the SIC for four-digit industries. The value of shipments of the top four firms relative to total shipments is used as a measure of concentration and the advertising data from Ornstein's study are used (p. 45). Shepherd provided an adjusted data series for the 1966 four-firm concentration ratios for the purpose of correcting what was believed to be a problem with the data similar to that used by Ornstein. Brush's studies of Ornstein's models using the corrected data led him to conclude that "correction of errors in the official Census concentration ratios has had little effect on the statistical estimation of the advertising concentration relationship . . ." (p. 985). For this reason, the initial data reported by Ornstein will be used. The advertising and concentration levels are measured across industries and the SIC codes are classified according to consumer versus producer goods, and durable versus nondurable goods. Many of the consumer nondurables are food industries. The cross-sectional data of four-digit industries are recorded over the years of 1947, 1963, and 1967.

Both Ornstein's and Strickland and Weiss' models are specified such that the intensity may decline with high levels of concentration. Ornstein's results supporting a declining intensity are statistically weak. Whereas, while Strickland and Weiss' statistical results are strong, there appears to be some difficulty with changes in the signs of their advertising relationship as they change the specification of their model (p. 1116). In the current model, the specification facilitates a nonlinear relationship initially assuming that the effect of concentration at least approaches some upper limit. The alternative where the intensity may decline is considered. The asymptotic function follows as the adjustments in ϵ_a and $\lvert\epsilon_d\rvert$ can be expected to approach limits such that $\lim \partial\epsilon_a/\partial C = 0$ and $\lim \partial\lvert\epsilon_d\rvert/\partial C = 0$.

The response to concentration may differ across industries simply because of the differences in both advertising and price elasticities for particular product categories. Finally, there may be reason to suspect that advertising intensity has increased since 1947 as a partial result from increased availability of advertising media. Each of the adjustments above have been ignored in most model specifications or at least have been treated in separate models.

Using the above arguments, the model specification below can be used to test the advertising-concentration relationship.

$$\frac{A}{S} = \exp^{(\tau_0 + \tau_1/C + \mu)}, \tag{1}$$

where

$\tau_0 = \beta_0 + \beta_1 PRO + \beta_2 DUR + \beta_3 T_1 + \beta_4 T_2$, and
$\tau_1 = \alpha_0 + \alpha_1 PRO + \alpha_2 DUR + \alpha_3 T_1 + \alpha_4 T_2$, and
A/S is the advertising-sales ratio (i.e., $0 \leq A/S \leq 100$);[1] C is the four-digit, SIC industry classification ($0 \leq C \leq 100$); PRO is the type of good (-1, producer; $+1$, consumer); DUR is a perishability measure (-1, durable; $+1$, nondurable); T is year where ($T_1 = 1$, $T_2 = 0$, for 1947; $T_1 = 0$, $T_2 = 1$, for 1963; $T_1 = 0$, $T_2 = 0$, for 1967). Note that τ_0 and τ_1 include the effects of PRO, DUR, and T, and both the level of advertising intensity and the response of advertising intensity to levels of concentration. Finally, the relationship has the asymptotic property where $\lim_{C\to 100} A/S = \exp^{(\tau_0 + .01\tau_1)}$, and the limit will change directly depending on the time and product classifications.

Equation (1) is estimated over a sample of 914 observations drawn from the Census of Manufac-

[1] Advertising was not deflated over the three time periods because both sales and advertising are influenced by inflation and the effects of inflation should be netted out in the intensity ratio.

Revisiting the Advertising-Concentration Issue

Ronald W. Ward and Robert M. Behr

Increases in advertising efforts are reasonably well documented among most U.S. industries (Nelson, p. 43). Yet, the economic controversy relating to the causal linkage between advertising intensity and changing market structures is not settled. Advertising can represent a major barrier to entry by its role in achieving product differentiation. In contrast, advertising may enhance competition with the dissemination of information through competitive advertising. While the advertising issues are varied and complex, this paper will set forth additional empirical evidence showing the relationship between advertising intensity and changing industry structure. In particular, the intensity of advertising across industry levels of concentration will be addressed and reference will be given to the food industries.

Studies suggesting that advertising leads to increased concentration have at the best been mixed (Blair). The argument suggesting that the advertising intensity varies positively (or negatively) with concentration has been slightly more definitive. Schmalensee argued that as concentration increases and profits rise, the marginal unit of sales becomes more profitable and it pays more to advertise to capture these additional sales (Mann, p. 150). Strickland and Weiss developed a simultaneous equation model with one equation relating advertising intensity to concentration where both variables are endogenous. Their analyses show that little bias is evident when the advertising intensity equation is estimated as a single equation in contrast to the simultaneous equation results (p. 1116). Because the primary focus of this analysis is to gain a better understanding of changing advertising intensity, the relationship is estimated in a single equation framework relying on Strickland and Weiss's conclusions as to the degree of bias that may occur.

The basic arguments for concentration influencing advertising intensity are two. (*a*) With increased concentration, firms recognize their rival's advertising reaction curve and will thus decrease their advertising effort on the assumption that it only has a neutralizing effect on the rival's advertising. Or, (*b*) with increased concentration, firms will substitute nonprice competition via advertising for price competition. The second argument implies a positive association between advertising and concentration, while the first argument suggests a negative relationship. These effects in turn lead to the public policy dialogue concerning the net social benefits derived from price versus nonprice competition.

Advertising-Concentration Linkage

Dorfman-Steiner's studies of price and nonprice decisions provide a clear linkage establishing the static optimal advertising decision rule to be related to both price and nonprice decisions (Needham, p. 87; Ward, p. 500). If ϵ_a and ϵ_d are the firm's elasticities of advertising and demand, then $A/S = \epsilon_a/|\epsilon_d|$ according to the static rule where A is advertising expenditures and S is sales.

The current issue is how the advertising intensity (A/S) changes with industry concentration (C) and how concentration influences both ϵ_a and $|\epsilon_d|$. The advertising and concentration relationship obviously is confounded in the effect concentration has on both elasticities. If concentration leads to greater economies of scale to advertising and increased product differentiation (i.e., $\partial\epsilon_a/\partial C > 0$) and a corresponding reduction in substitutes (i.e., $\partial|\epsilon_d|/\partial C < 0$), then it always follows that advertising intensity will increase with concentration. The adjustments in ϵ_a and ϵ_d are not altogether clear, however.

The firm's advertising elasticity further has been shown to be related to the rival's advertising response (Needham, p. 85). Assuming that the industry structure is such that rival response is not apparent, then the arguments for a neutralizing and/or retaliatory advertising response are not relevant. However, as concentration increases anticipated rival response can not go unnoticed.

The concentration-intensity linkage is further confounded when one turns to the effects of concentration on the elasticity of demand. Price elasticity of demand is related to the rival's response, and this response is influenced by the level of concentration. With no rival response it is relatively easy to show that the firm's demand becomes less elastic with increased concentration. If increased rival response to firm price changes is anticipated, advertising will be substituted for price competition. However, as concentration increases, rival impact may be lessened and the need to substitute nonprice for price competition would be reduced.

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western Canada, the only significant factor is the size of the Canadian crop relative to local demand. After navigation is reopened in the spring, both local production relative to demand and the availability of western feed grains have significant effects. The relative insensitivity of the variable representing western feed grains suggests that Canadian policy affecting western grains is not normally as significant a factor in determining Ontario corn prices as is often perceived in Canada. This inference must, however, be qualified by the difficulties in measurement of the variable and by the coefficients on *D*73 which suggest that events in western Canada are important in extreme circumstances.

That the basis for corn in southwestern Ontario adjusts to local market conditions as theory implies provides some reassurance about the market's pricing performance. However, the analysis does not purport to provide evidence on whether prices are optimum in any sense. From a practical standpoint, the analysis provides information that could be useful to local traders and hedgers in understanding the factors which affect the basis.

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References

Brennan, M. J. "The Supply of Storage." *Amer. Econ. Rev.* 47(1958):50–72.

Driscoll, J. L., and L. V. Blakley. *Expected Returns for Hedging Stored Wheat in Oklahoma.* Oklahoma State University Agr. Exp. Sta. Bull. B-677, Apr. 1970.

Gray, Roger W. "Price Effects of a Lack of Speculation." *Food Res. Inst. Stud.* 7(Suppl. 1967):117–94.

———. "The Characteristic Bias in Some Thin Futures Markets." *Food Res. Inst. Stud.* 1(1960):296–312.

Heifner, R. G. *The Gains from Basing Grain Storage Decisions on Cash-Futures Spreads in Michigan.* Michigan State University Exp. Sta. Quart. Bull., vol. 48, no. 4, May 1966.

———. *Hedging Potential in Grain Storage and Livestock Feeding.* USDA ERS Agr. Econ. Rep. No. 238, Jan. 1973.

Kenyon, David E., and Paul K. Blakely. *Alternative Basis Estimation Procedures and Hedging Strategies for Corn and Soybean Producers in Selected Virginia Markets.* Dep. Agr. Econ. Bull. AE18, Virginia Polytechnic Institute and State University, Sept. 1974.

Martin, Larry. *Commodity Futures Markets—Hedging Opportunities for Ontario Grain Corn and Soybean Producers.* School of Agr. Econ. & Extens. Educ. Bull. AE/73/12, University of Guelph, July 1973.

Martin, Larry, and Gary Storey. "Temporal Price Relationships in the Vancouver Rapeseed Futures Market and Their Implications to Farm Prices." *Can. J. Agr. Econ.* 23(1975):1–12.

Regli, P. *Pricing Corn in Ontario.* Ontario Ministry of Agriculture and Food Fact Sheet AGDEX 111/840, Ontario 1975.

Ward, Ronald W., and Frank A. Dasse. "Empirical Contributions to Basis Theory: The Case of Citrus Futures." *Amer. J. Agr. Econ.* 59(1977):71–80.

Weymar, Helmut. "The Supply of Storage Revisited." *Amer. Econ. Rev.* 56(1966):1226–34.

Working, H. "Theory of the Inverse Carrying Charge in Futures Markets." *J. Farm Econ.* 30(1948):1–28.

Dummy Variables

Dummy variable D72 was included for January through July of crop year 1972 (i.e., calendar year 1973) to account for an inversion in corn futures prices during this period. As a result, U.S. export prices apparently were based on the spot instead of the nearby futures price, and the Ontario basis showed substantial premia over the futures prices.

Dummy variable D73 was included for the months of November through June (except March) of crop year 1973. During that crop year, the Canadian Wheat Board established initial prices for Board grains at high levels. This led to the delivery of most board grains to the Canadian Wheat Board, which then exported them. As a result, there was little movement of western grains to the East and therefore a premium was bid on Canadian corn. In March 1974, when navigation opened, the premium disappeared, reflecting expected U.S. corn imports. However, little U.S. corn was imported until July; so the premium on Canadian corn reappeared from April through June.

Dummy variable D74 was included for July and August of crop year 1974. The 1974 corn crop in Canada was of record size. In the fall, trade sources believed Canada would be in a surplus position and, accordingly, exported a record 10 million bushels early in the crop year. Subsequently, it became apparent that domestic demand for corn had been underestimated and substantial amounts of U.S. corn were imported late in the crop year.

The results in table 1 indicate that the market aberrations each had considerable positive impact on the local basis, as expected.

Sensitivity of Basis Residual to the Explanatory Variables

It is of interest to show the sensitivity of basis to changes in the explanatory variables. While this normally would be done using elasticities, elasticities are of little meaning in this analysis because of the small magnitude of the dependent variables. Instead, the absolute change in basis associated with a 10% change from the mean in each explanatory variable is presented in table 2.

Data in table 2 indicate that basis residual is quite sensitive to most of the variables. Of the eight months for which the ratio variable (*IPOC*) is significant, a 10% change results in 3¢ per bushel or more change in basis in six months. Domestic corn consumption averaged about 110 million bushels per year over this period. Hence, the 10% change in *IPOC* represents approximately 8.5 million bushels in Canadian production.

The basis residual in November and December is quite sensitive to Canadian and U.S. corn production. The greater sensitivity implicit in the U.S. production variable is initially surprising; however, a 10% change in U.S. production is more than five times total Canadian production.

Basis residual for May through July is not particularly sensitive to western feed grain availability. However, during the sixteen years of the analysis, shipments of western feed grains to eastern Canada varied from virtually nil to 1.03 million tons. A change in shipments of 10% from the mean is only 72,000 tons; but year-to-year changes obviously can be far in excess of this.

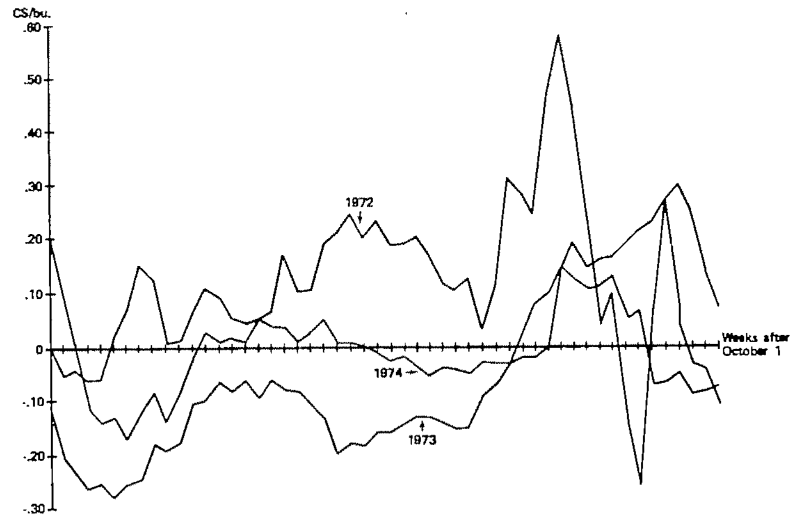
Conclusions

The analysis suggests that a substantial amount of the variation in the southwestern Ontario basis is explained by variables reflecting local market conditions. During the fall months, the size of the Canadian and U.S. crops is the most important factor. During the winter, when the eastern Canadian market is essentially closed except to relatively costly rail access from the United States and

Table 2. Absolute Change in Basis Associated with a 10% Change in Each Explanatory Variable

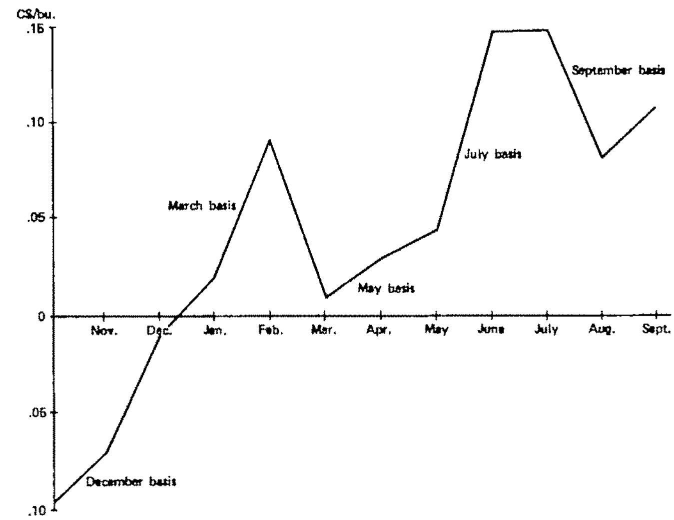
Month	Mean of Basis Residual	Change in Basis from a 10% Change in:[a]			
		IPOC	*CCP*	*USCP*	*WFGA*
		($/bu)			
October	−.079	−.046			
November	−.077		−.027	.072	
December	−.044		−.020	.050	
January	−.022	−.035			
February	.099	−.037			
March	−.005	−.033			
April	.005	−.031			
May	.026	−.021			−.011
June	.071	−.016			−.013
July	.107	−.034			−.010

[a] Means of the explanatory variables are: *IPOC* = .76 = ratio of Canadian production to consumption; *CCP* = .86 = 86 mil. bu.; *USCP* = 5.7 bil. bu.; *WFGA* = .72 = 720 thousand tonnes.



Note: See footnote [2] for explanation of figure.

Figure 1. Weekly basis for corn, Chatham, Ontario, crop years Oct.–Sept. 1972, 1974, 1975



Note: See footnote [2] for explanation of figure.

Figure 2. Monthly corn basis, averaged over crop years 1971–75, Chatham, Ontario

services. Hence, the size of the U.S. crop is a proxy for the demand for these services. Both factors suggest that the size of the U.S. corn crop would be related directly to the Ontario basis during the fall.

Again, the analysis confirms the expectation as indicated by the coefficients for November and December in table 1.

Western Feed Grain Availability

Western feed grain availability is included as a proxy for Canadian Wheat Board and federal feed grain pricing policy. These policies have changed often and markedly during recent years and are therefore both unquantifiable and unpredictable. However, a measure of availability is included on the ground that competition from western feed grains should be expected to affect the eastern corn basis. Availability was measured initially as stocks of western feed grains in lakehead and eastern elevators. However, in initial runs, this variable was found to carry no statistical significance. This is likely because the data do not separate stocks intended for domestic and export markets.

As an alternative, actual movements of western feed grains to the domestic eastern market were used in the analysis. This variable is expected to be related inversely to the basis. The expectation is confirmed by the coefficients on the variable from May onward in table 1.

Table 1. Monthly Equations for Ontario Basis Residual (t-values in parentheses)

Month	Intercept	*IPOC*	*CCP*	*USCP*	*WFGA*	*D72*	*D73*	*D74*	R^2	*SEE*
October	.384	−.609							.68	.045
		(−5.26)								
November	−.532		−.313	.126			.139		.85	.042
			(−6.97)	(4.67)			(3.02)			
December	−.361		−.232	.088			.201		.76	.050
			(−4.36)	(2.77)			(3.68)			
January	.334	−.458				.075	.097		.66	.049
		(−3.59)				(1.49)	(1.89)			
February	.372	−.493				.116	.079		.69	.049
		(−3.83)				(2.27)	(1.51)			
March	.313	−.440				.238			.75	.049
		(−3.51)				(4.71)				
April	.284	−.402				.206	.188		.82	.045
		(−3.41)				(4.40)	(3.94)			
May	.321	−.278			−.157	.146	.294		.73	.062
		(−1.64)			(−2.26)	(2.14)	(4.41)			
June	.335	−.217			−.187	.346	.193		.71	.073
		(−1.09)			(−2.31)	(4.31)	(2.48)			
July	.514	−.441			−.142	.292		.166	.76	.061
		(−2.64)			(−2.22)	(4.68)		(2.49)		

Note: Units in which the explanatory variables are measured are: *IPOC*, ratio of Eastern Canadian production to Eastern Canadian consumption with 1 occurring when the two are equal; *CCP*, 1 = 100 million bu.; *USCP*, 1 = 1 billion bu.; *WFGA*, 1 = 1 million tonnes.

these areas. The latter is relatively costly and tends to result in Ontario prices being bid up relative to the futures price.

Great Lake-St. Lawrence shipping is opened during March or April, resulting again in increased competition for the eastern Canadian market and a narrower basis. During the late spring and summer, Ontario prices have tended to increase relative to the futures price because Ontario's crop has not been sufficiently large to meet eastern Canada's demand during these months.

The resulting seasonal basis pattern is apparent in figure 2, which contains the average nearby Chatham basis for each month of crop years 1971–75. To account for this seasonality, and on the hypothesis that different factors affect the basis in different months, a separate equation was estimated for each month of the crop year. The results in table 1 tend to support this hypothesis. (As in figure 1, basis in figure 2 is calculated from the nearby future and is adjusted for exchange rates.)

Ratio of Eastern Canadian Corn Production to Consumption

This variable was included to account for competition in the eastern Canadian market between domestic and U.S. corn, as discussed in the previous section. As the ratio approaches or exceeds unity, domestic and imported corn would compete east of Montreal or on the export market and the Chatham basis would be bid down for the reasons explained earlier. Thus, the variable should be related inversely to the basis throughout the crop year.

The results are as expected. The ratio is significant in all months except November and December when harvest variables explain much of the basis variation (see below).

Canadian Corn Production

This variable was included because of the expected relationship between the size of the crop and storage charges in Ontario. The larger the crop, the greater the demand for storage; hence, the local basis would be expected to fall to cover increased storage costs.

The results are consistent with the expectation. The Canadian crop is a significant variable during the harvest period as would be anticipated because this is the period when demand for storage is greatest.

U.S. Corn Production

U.S. corn production is included for two reasons. First, the size of the crop could be a determinant of short hedging pressure at harvest time. A large U.S. crop would place downward pressure on futures prices. Second, a large U.S. crop would motivate shipping more corn through the Great Lakes-St. Lawrence system in the fall before the close of navigation. This, in turn, would increase the demand for transport and handling services during this period, thereby increasing the costs of these

Notes

The Impact of Beef By-Product Exports on Live Cattle Prices

Martin Blake and Tom Clevenger

Since the early 1960s, beef producers have been concerned about price-depressing effects of beef and veal imports on live cattle prices (U.S. Senate 1964a,b, 1976a,b, 1978). The concern about imports reached a peak in 1964 with the passage of the Meat Import Act. This concern continues as evidenced by the House of Representatives bills 1995, 1996, 1997, and 1998 currently under consideration by the 96th Congress. Each of these bills proposes further restrictions on meat imports. However, both imports and exports of cattle, beef, veal, and beef by-products have an impact on live cattle prices. Imports are only one side of the larger issue of international trade in these products. For example, the dollar value of exports has been considerably greater than the dollar value of imports of beef, veal, and beef by-products for three of the four years, 1975–1977 (table 1).

Much attention has been given to the adverse impact of imports on domestic live cattle prices through models which directly examined this relationship or by imputing the impacts from econometric models of the beef sector (Edwards, Ehrich and Usman, Folwell and Shapouri, Freebairn and Rausser, Houck 1974, 1977, Jackson, Langemeier and Thompson, and Schmitz and Nelson). However, these researchers have neglected the impact of beef and beef by-product exports on domestic live cattle prices. In this note, these impacts are quantified. Beef exports are not examined because they comprised about 0.35% of total U.S. beef production in 1977 (Blake and Coppersmith).

The Model

The prices packers are willing to pay for live cattle are a function of the prices they receive for the by-products and the price they receive for carcasses. Thus, live cattle price (LCP) may be divided into two components, one component attributable to by-products (BP) and the other to beef (B),

$$LCP = BP + B. \tag{1}$$

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The portion of live cattle price attributable to beef is a function of the supply and demand factors for beef including net imports of beef. The portion of live cattle prices attributable to beef by-products may be thought of as a function of the supply and demand factors for these by-products, including net exports of beef by-products. However, live cattle are purchased and slaughtered primarily for their value as beef, not for their by-product value. Thus, the supply of beef by-products may be viewed as derived from the number of cattle slaughtered, not as a function of the price of by-products. Because of this, the price of beef by-products can be viewed as a function of demand factors alone. This relationship may be expressed as

$$BP = f(E, DDBP), \tag{2}$$

where BP is the portion of live cattle price attributable to by-products; E, the exports of beef by-products; and $DDBP$, the domestic demand for beef by-products.

The equilibrium price of by-products is determined through use of the market clearing condition. Quantity supplied is composed of imports (I) and domestic production (DP), while quantity demanded is composed of domestic demand (DD) and exports (E). This may be expressed as

$$DP + I = DD + E, \text{ or,} \tag{3}$$

$$DP = DD + (E - I), \text{ and} \tag{4}$$

$$1 = \frac{DD}{DP} + \frac{E - I}{DP}. \tag{5}$$

Because $DP = DD + (E - I)$, estimating BP as a function of $\frac{DD}{DP}$, $\frac{E-I}{DP}$, and an intercept term would lead to a problem of perfect multicollinearity. Thus, a formulation that includes both $\frac{E-I}{DP}$ and an intercept term indirectly accounts for domestic demand. The equilibrium price of beef by-products may be expressed as

$$BP = f\left(\frac{E - I}{DP}\right). \tag{6}$$

The measure employed, the portion of live cattle price attributable to by-products, is from the U.S. Department of Agriculture (USDA) *Livestock and Meat Statistics*, which reports the portion of gross

Table 1. Value of U.S. Imports and Exports of Cattle, Beef, Veal, and Beef and Veal By-Products, 1975–78

Item	1975 Imports	1975 Exports	1976 Imports	1976 Exports	1977 Imports	1977 Exports	1978[a] Imports	1978[a] Exports
	(million $)							
Live cattle and calves	82.2	77.2	166.0	92.2	189.8	66.8	254.9	94.1
Beef and veal[a]	661.4	70.1	910.7	110.1	834.2	121.4	1,287.4	193.8
Beef tallow	2.0	398.1	1.2	353.9	0.7	496.8	0.4	520.0
Beef and veal offal[b]	2.0	67.8	1.7	90.3	1.9	119.9	2.9	150.5
Hides and skins	8.2	273.8	18.7	426.1	17.4	557.1	20.5	652.0
Total	755.8	887.0	1,098.3	1,072.6	1,044.0	1,362.0	1,565.1	1,610.4

Sources: U.S.D.A., *Livestock and Meat Statistics, Supplement 1978*, and U.S.D.A. *U.S. Foreign Agricultural Trade Statistical Report, Calendar Years 1976–78.*

[a] Preliminary.

[b] Although the export figures are for beef and veal offal, the import data include all animal offal.

farm value attributable to edible and inedible by-products. Gross farm value is the market value to producers for a quantity of live animal equivalent to one pound of retail cuts.

The farm by-product allowance has accounted for about 10.3% of the gross farm value since 1970 (Blake and Coppersmith). The gross farm value and farm by-product allowance for beef may be transformed to an equivalent liveweight price per pound by dividing by the farm product equivalent. The farm product equivalent is an estimate of the amount of live animal needed to produce one pound of retail cuts. The USDA reported a farm product equivalent for beef of 2.36 prior to 1970 and gradually increased it to 2.40 in 1976. The endogenous variable used in this study is the transformed farm by-product allowance (*FBPA*). This variable measures the portion of the average liveweight farm price of cattle in cents per pound attributable to beef by-products. Because live cattle prices have been divided into two components (1), use of *FBPA* as the endogenous variable permits an examination of the impacts that beef by-product exports have on live cattle prices. The theoretical relationship estimated in this article is

$$FBPA = f\left(\frac{E - I}{DP}\right). \tag{7}$$

Major by-products of beef production are edible tallow, inedible tallow and grease, hides and skins, and beef offal. Data are available on imports and exports of edible and inedible tallow in the U.S. Department of Commerce's *Current Industrial Reports* and for imports and exports of skins and hides in USDA's *Agricultural Statistics*. Data on imports and exports of beef offal are available in *Foreign Agricultural Circular—Livestock and Meat* (USDA).[1] Data are also available on the domestic production of edible and inedible tallow in *Current Industrial Reports*. Although no data are available for domestic production of skins and hides or beef offal, reasonable estimates for these quantities can be derived. An estimate of the domestic production of skins and hides is obtained from the number of cattle and calves commercially slaughtered (USDA *Livestock and Meat Statistics*). An estimate of the domestic production of beef offal is obtained by multiplying the number of cattle commercially slaughtered by 36.1 pounds of offal production from a 1,000 pound animal, a figure currently used by USDA.

The exogenous variables used in this analysis are derived from these data on imports, exports, and domestic production of beef by-products. Net exports as a percentage of domestic production for each of the major by-product items are the four exogenous variables used in this analysis.

A major percentage of beef by-products is exported. U.S. exports of inedible beef tallow and grease have averaged 45.1% of production 1970–77. Exports of skins and hides have averaged 51.1% of production for the same period. Beef offal and edible tallow exports have been relatively less important, averaging 12.5% and 4.7% of production, respectively, 1970–77 (Blake and Coppersmith).

Because imports of these by-products are very small, net exports are used rather than accounting directly for by-product imports. Using net exports divided by the domestic production for each of these by-products establishes the relative importance of the export market for each by-product and permits an evaluation of its impact on the portion of live cattle price attributable to by-products.

[1] Data are available on beef offal exports in the *Foreign Agricultural Circular—Livestock and Meat* from 1966 to date. One method of obtaining a longer time series for beef offal exports is to use exports of total fresh or frozen variety meats, reported in *Agricultural Statistics*. Exports of total fresh or frozen variety meats include not only beef offal, but offal from other animals. A correlation coefficient of 0.98 was estimated for exports of beef offal and exports of total variety meats for 1966–77.

The estimated model for the time period 1958–77 is

$$FBPA = \underset{(1.69)}{3.66} - \underset{(-1.66)}{0.09}\ PCTIT + \underset{(1.77)}{0.10}\ PCTET + \underset{(1.15)}{0.03}\ PCTSH + \underset{(1.48)}{0.11}\ PCTO,$$
$$R^2 = 0.763 \qquad F = 12.09$$

where t-values are shown in the parentheses; *FBPA* is the portion of the annual average liveweight farm price of cattle attributable to beef by-products (cents per pound); *PCTIT*, annual net exports of inedible beef tallow and grease as a percentage of domestic production; *PCTET*, annual net exports of edible beef tallow as a percentage of domestic production; *PCTSH*, annual net exports of cattle hides and calf skins as a percentage of domestic production; and *PCTO*, annual net exports of beef offal as a percentage of domestic production.

Analysis

The R^2 of 0.763 implies that the export market accounts for a major share of the variation in the portion of annual average liveweight farm cattle price that is attributable to by-products. The F-value of this model was 12.09, which is significant at the 99.9% level.

Because beef tallow is a major dollar value component of beef by-product exports (table 1), the negative coefficient for *PCTIT* was not expected. This negative sign would imply that for each 1% increase in the amount of inedible tallow production that was exported, the average annual domestic live cattle price declined by 0.09¢ per pound. This negative impact on domestic live cattle prices may be attributed to the large percentage of total world exports of inedible tallow accounted for by U.S. exports. For the period 1973–75, U.S. exports of inedible tallow comprised about 66% of total world tallow exports (*Agricultural Statistics*). Because total world tallow exports include both edible and inedible tallow, the 66% figure is a conservative estimate of the importance of U.S. inedible tallow exports in the world market. The quantity of inedible beef tallow exports averaged about 200 times the exports of edible beef tallow. With the United States having about two-thirds of the world inedible tallow export market, it is possible for additional U.S. exports to have a price-depressing effect on this market. This appears to have been the case for 1958–77, as indicated by the negative sign for the regression coefficient *PCTIT*. The coefficient for *PCTIT* was significant at the 88% level.

The mean value of *PCTIT* was 45.13, which resulted in a −4.06¢ per pound impact on live cattle prices. *PCTIT* ranged from 38.89 in 1958 which resulted in a −3.50¢ per pound impact on live cattle prices, to 52.33 in 1971, which resulted in a −4.71¢ per pound impact on live cattle prices.

Coefficient for *PCTET* was significant at the 90% level. The coefficient of *PCTET* may be interpreted as a 1% change in the amount of edible tallow production that was exported resulting in a 0.10¢ per pound change in live cattle prices. The mean value of *PCTET* was 3.17, which had a 0.32¢ per pound impact on live cattle prices. *PCTET* ranged from 0.58 in 1966, which resulted in a 0.06¢ per pound impact on live cattle prices, to 11.38 in 1974, which resulted in a 1.14¢ per pound impact on live cattle prices.

The coefficient for *PCTSH* indicates a 1% change in the amount of calf skin and cattle hide production that was exported resulted in a 0.03¢ per pound change in live cattle prices. Although the coefficient appears small relative to the others, the mean value of *PCTSH* was 37.18, which resulted in a 1.12¢ per pound impact on live cattle prices. *PCTSH* ranged from 11.11 in 1959, which resulted in a 0.33¢ per pound impact on live cattle prices, to 66.24 in 1972, which resulted in a 1.99¢ per pound impact on live cattle prices. The coefficient for *PCTSH* was significant at the 73% level.

The coefficient for *PCTO* was significant at the 84% level. This coefficient indicates that a 1% change in the amount of beef offal production that was exported resulted in a 0.11¢ per pound change in live cattle prices. The mean value for *PCTO* was 17.78, which resulted in a 1.96¢ per pound impact on live cattle prices. *PCTO* ranged from 7.93 in 1958, which resulted in a 0.87¢ per pound impact on live cattle prices, to 24.87 in 1977, which resulted in a 2.74¢ per pound impact on live cattle prices.

Implications

The impacts that beef by-product exports have had on live cattle prices can best be seen by looking at the high and low values for each of the by-product variables during the time period considered. The impacts that exports of inedible tallow, edible tallow, skins and hides, and offal have had on the price of live cattle per hundred weight ranged from −$3.50 to −$4.71, $0.06 to $1.14, $0.33 to $1.99, and $0.87 to $2.74, respectively. These may be compared with the impact of beef imports on live cattle prices estimated by Freebairn and Rausser. They examined the effect of a 200 million pound increase in beef imports on live cattle prices and reported that the price per hundredweight of slaughter steers would decline by $0.56, cull cows would decline by $0.94, and feeder calves would decline by $0.69. During 1970–76, the lowest level of fresh or frozen beef and veal imports was 1,079 million pounds in 1974, and the highest level was 1,349 million pounds in 1973 (USDA *Agricultural Statistics*). Thus, the largest change in imports during this period was 270 million pounds. Hence, the 200 million pound increase in beef imports examined by Freebairn and Rausser is nearly as large as the difference between the largest and smallest levels of beef and veal imports 1970–76. As may be

seen, the impacts of beef by-product exports are large relative to the impact of beef imports.

Currently, there is considerable interest in beef imports. One implication of this study is that some, or even most, of this attention might profitably be shifted to the by-product export markets. For example, there seems to be much potential for increasing live cattle prices by examining the markets for inedible tallow. Prior to 1972, the negative price impact of inedible tallow exports exceeded the sum of the positive price impacts of the other three by-product exports. The reverse was true for 1972–77. This reverse has not been due to any great decline in the impact of inedible tallow exports, but has resulted from a rather large increase in the sum of the other three components. The large negative effect of inedible tallow exports on live cattle prices and the fact that the United States accounts for about two-thirds of world exports for this commodity imply that live cattle prices may be increased by allocating less inedible tallow to the export market. A full assessment of this potential requires detailed information on the price elasticity of demand in the various markets for inedible tallow. Furthermore, such knowledge of elasticities would be useful for all beef by-products.

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References

Blake, Martin J., and Robert L. Coppersmith. *International Trade in Cattle, Beef and Beef By-Products*, New Mexico State University Coop. Ext. Ser. 400Z-11, Jan. 1979.

Edwards, John A. *Beef Imports and the United States Beef Cattle Market.* Oregon State University Agr. Exp. Sta. Spec. Rep. 178, 1964.

Ehrich, Rollo L., and Mohammed Usman. *Demand and Supply Functions for Beef Imports.* University of Wyoming Agr. Exp. Sta. Bull. 604, Jan. 1974.

Folwell, Raymond J., and Hosein Shapouri. *An Econometric Analysis of the U.S. Beef Sector.* College of Agr. Res. Center, Tech. Bull. 89, Washington State University, Sept. 1977.

Freebairn, J. W., and Gordon C. Rausser. "Effects of Changes in the Level of U.S. Beef Imports." *Amer. J. Agr. Econ.* 57(1975):676–88.

Houck, James P. "A Proposed Change in the Meat Import Quota Formula: A Move toward Stability." Statement before the U.S. International Trade Commission in connection with Investigation No. 332-85, 17 July 1977.

Houck, James P. "The Short-Run Impact of Beef Imports on United States Meat Prices." *Aust. J. Agr. Econ.* 18(1974):60–72.

Jackson, Geoffrey H. *The Impact of Eliminating the Quota on United States Imports of Beef.* Cornell University Agr. Exp. Sta. Agr. Econ. Res. 338, Jan. 1972.

Langemeier, Larry, and Russell Thompson. "Demand, Supply and Price Relationships for the Beef Sector, Post World War II Period." *J. Farm Econ.* 49(1967):169–83.

Schmitz, Andrew, and Ray Nelson. "The Impact of United States Beef Imports." *Conditions of Competition in U.S. Markets between Domestic and Foreign Live Cattle and Cattle Meat Fit for Human Consumption*, Appendix E. U.S. International Trade Commission, Pub. 842, Washington, D.C., Nov. 1977.

U.S. Department of Agriculture. *Agricultural Statistics*, various issues.

———. Economics, Statistics, and Cooperatives Service. *U.S. Foreign Agricultural Trade Statistical Report, Calendar Year*, various issues.

———. Economics, Statistics and Cooperatives Service and Agricultural Marketing Service. *Livestock and Meat Statistics*, various issues.

———. *Foreign Agricultural Circular—Livestock and Meat*, FLM MT5-76, various issues.

U.S. Department of Commerce, Bureau of Census. *Current Industrial Reports*, M20K, various issues.

U.S. Senate, Committee on Finance. *Hearings on Amendment 465 to Restrict Imports of Beef, Veal, Lamb, and Mutton into the United States.* 88th Cong., 2nd sess., 1964a.

———. *Hearings on Amendment 465 and 467 to Restrict Imports of Beef, Veal, Lamb, and Mutton into the United States.* 88th Cong., 2nd sess., 1964b.

———. *Hearings before the Subcommittee on International Trade on Meat Imports*, 94th Cong., 2nd sess., 1976a.

———. *Hearings on Meat Import Quota Amendments*, 94th Cong., 2nd sess., 1976b.

———. *Hearings on Proposed Amendments to the Meat Import Quota Act*, 95th Cong., 2nd sess., 1978.

Factors Affecting Corn Basis in Southwestern Ontario

Larry Martin, John L. Groenewegen, and Edward Pidgeon

Pricing performance of futures markets for seasonally produced, storable commodities often has been evaluated in part by determining whether or not the basis at the delivery point reflects the theoretical factors expected to affect it.[1] These factors include marginal net storage costs (Working, Brennan, and Weymar), market liquidity (Gray 1960 and 1967, Martin and Storey) and market characteristics unique to a specific commodity (Ward and Dasse).

Futures markets for these commodities also are used to establish current prices at nondelivery points. Following the argument of Ward and Dasse, if pricing performance at nondelivery points is satisfactory, local basis should reflect market characteristics unique to the local area because it is a measure of the value of a commodity relative to the delivery point.

Futures markets also are used to forward price grains at nondelivery points either by hedging or forward contracting. In either case, expectations of basis are important in establishing forward prices. Most extension literature stresses the importance of understanding the local basis and asserts that local basis is affected by local market conditions (e.g., Kenyon and Blakely). Yet for the few cases in which analyses of local basis have been undertaken, relatively naive models have been used to explain basis variations, such as moving averages or basis at the time a hedge is initiated (Kenyon and Blakely, Driscoll and Blakley, and Heifner 1966). The ability to explain nondelivery point basis using variables reflecting local market conditions is important for evaluating pricing performance and for providing local traders and hedgers an understanding of the factors which cause variations in the local basis.

In this paper an analysis of nondelivery point basis is undertaken with the objective of providing information for these two purposes. The analysis is carried out by constructing a hypothetical model to explain variations in local basis and then testing it by applying it to basis data for southwestern Ontario.

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[1] Basis is simply the difference between the spot and a futures price on a given day. Our concern here is with the basis when corn is marketed. This will be termed "ending basis."

The Ontario Market for Corn and Its Pricing Mechanism

Ontario produces most of Canada's corn, and production has trended upward from 33 million bushels in 1962 to 154 million bushels in 1977. Because of available heat units, the majority of the province's production occurs in the southwestern counties. The major pricing point for southwestern Ontario is Chatham, an inland terminal with rail links to Lake Huron, eastern Ontario, and Montreal, where Ontario corn normally competes with imported U.S. corn.

As a result of the increasing trend in Ontario's corn production, the province gradually has moved from a deficit to a surplus position. At the same time, variations around the trend and cyclic growth in the province's livestock production have resulted in substantial year-to-year variation in the local supply-demand balance, contributing to large variations in the local basis. For example, during crop years 1962–71, Martin noted that the Chatham basis in late October varied from \$.20 under the December futures price to \$.07 over, while the mid-June basis varied from \$.15 under to \$.13 over the July contract. Since 1971, variations in the Chatham basis have become even larger, as is illustrated by the weekly basis observations in figure 1 for crop years 1972, 1974, and 1975.[2]

Three factors in the above discussion—the landlocked location of the Chatham market, variations in the local supply-demand balance, and competition with U.S. corn—are important in establishing prices and basis in southwestern Ontario. These three factors combine to result in three alternative pricing and basis situations for southwestern Ontario. First, when Ontario's production is less than the province's demand, Ontario and U.S. corn compete in central or eastern Ontario. The price in southwestern Ontario tends to be the price of U.S. corn at Chicago plus lake freight to Canada (Montreal or Prescott) plus tariff, elevation, and rail transfer cost to, e.g., central Ontario less rail transfer from Chatham to central Ontario.

The second occurs when Ontario's production

[2] These are obtained from Thursday market closes each week, adjusted to Canadian dollars using weekly exchange rates, and represent the nearby basis—i.e., from October through November, basis is calculated from the December contract; from December through February, it is calculated from the March contract, etc. Three crop years were selected to show the range of variation.

exceeds her demand and Ontario and U.S. corn compete in Quebec and the Maritimes. In this case, no rail transfer costs are incurred for U.S. corn and the southwestern Ontario price tends to be the landed price of U.S. corn at Montreal less rail costs from Chatham to Montreal.

The third case occurs when eastern Canada has surplus production and Canadian and U.S. corn compete on the export market. (Because the United States imposes a \$.25 tariff on imported corn, Canadian exports to the United States are, for all practical purposes, precluded.) Under these circumstances, U.S. corn does not enter Canada but is transferred to oceangoing vessels and no tariff is charged. Hence the southwestern Ontario price tends to be the price of U.S. corn at Montreal (in bond, not including tariff) less rail costs from Chatham to Montreal.

The foregoing indicates that the southwestern Ontario price (and basis) falls relative to the price of U.S. corn as the point of competition moves eastward. Implicit in this statement is the hypothesis that the local (eastern Canada) supply-demand balance is an important variable in explaining basis variations.

The present discussion omits a number of other factors which may affect the basis and which are addressed in the following section. However, it is sufficient to form a notion about the general relationship between U.S. and Ontario corn prices and to form a basis residual used in the analysis.

Because of the time and distance required to ship corn from Chicago to Montreal, the U.S. export-offering price normally is the nearby futures price plus a loading charge. This has been documented by Regli and confirmed by the authors in conversations with the trade in Canada. Based on this tendency, the foregoing discussion, and an initial assumption that the only influences on the Chatham price are the Chicago price and all costs incurred to move Ontario and Chicago corn to Montreal, the Chatham price normally would be the demand area price at Montreal less transfer and handling charges between Chatham and Montreal. The demand area price at Montreal is the nearby futures price and the loading charge at Chicago (adjusted for the current exchange rate) plus transfer, tariff, and handling charges to Montreal. Hence, given the assumptions made, the Chatham basis would be equal to the loading charge at Chicago plus transfer, tariff, and handling charges from Chicago to Montreal, less transfer and handling charges from Chatham to Montreal.

Of course, as indicated previously, Montreal is not always the Canadian pricing point for U.S. corn; moreover, other variables affect the Chatham basis. Thus, the assumptions made above must be relaxed, and the Chatham basis at a given point in time consists of two components: net spatial costs (loading, tariff, transfer, and handling charges) and a basis residual. Rail costs from Chatham to Montreal, the tariff, and average annual vessel rates are known and can be acquired as time-series data. However, vessel rates, handling, and loading charges vary within a year with changes in the demand for and supply of these services and time-series data on them are not available. The known component can be eliminated from the model while the unknown component is included in the basis residual.

The remaining basis residual is the focus of our empirical analysis. The model developed to explain the residual is presented below.

The Model and Results

The model to explain basis residual is specified as

$$BR_t^i = f(S^i, IPOC_t, CCP_t, USCP_t, WFGA_t, D_i),$$

where BR_t^i is the basis residual in month i of crop year t, as defined above; S^i is seasonality; $IPOC_t$ is a ratio of eastern Canadian production to eastern Canadian consumption; CCP_t is Canadian corn production in year t; $USCP_t$ is U.S. corn production in year t; $WFGA_t$ is availability of western feed grains to the domestic market in eastern Canada; and D_i is a series of (0–1) dummy variables which represent short-run pricing aberrations.

The reasons for including each variable and its expected effect on the basis will be developed below along with the results of the analysis. Equations for average monthly basis residual were estimated with data from crop years 1962 through 1976, using ordinary least squares procedures. All variables were included initially in the estimating equations. Where preliminary estimations resulted in t-values of less than 1.0 on individual variables, those variables were deleted and the equations reestimated. The final equations are presented in table 1 for October through July. The results for August and September showed that the only market variable having a significant effect on basis in these months is, not surprisingly, the size of the succeeding crop year's crop. Since the succeeding crop's size is not known in August or September, it must be concluded that basis in these months is exceeding difficult to predict.

Seasonality

A number of factors combine to cause seasonality in the basis at Chatham. As with most seasonally produced commodities, harvest period prices in Ontario are bid down relative to the futures price until the harvest glut is cleared from the producing area. During the late fall and winter, the Ontario basis exhibits the characteristic increase which is expected after a harvest glut has been reduced. For Ontario, this seasonal pattern is exacerbated because Great Lake-St. Lawrence shipping is closed and Ontario corn competes only with U.S. or Western Canadian feed grains moved into Eastern terminals in the fall or with grain shipped by rail from

Table 1. Monthly Equations for Ontario Basis Residual (*t*-values in parentheses)

Month	Intercept	*IPOC*	*CCP*	*USCP*	*WFGA*	*D72*	*D73*	*D74*	R^2	*SEE*
October	.384	−.609 (−5.26)							.68	.045
November	−.532		−.313 (−6.97)	.126 (4.67)			.139 (3.02)		.85	.042
December	−.361		−.232 (−4.36)	.088 (2.77)			.201 (3.68)		.76	.050
January	.334	−.458 (−3.59)				.075 (1.49)	.097 (1.89)		.66	.049
February	.372	−.493 (−3.83)				.116 (2.27)	.079 (1.51)		.69	.049
March	.313	−.440 (−3.51)				.238 (4.71)			.75	.049
April	.284	−.402 (−3.41)				.206 (4.40)	.188 (3.94)		.82	.045
May	.321	−.278 (−1.64)			−.157 (−2.26)	.146 (2.14)	.294 (4.41)		.73	.062
June	.335	−.217 (−1.09)			−.187 (−2.31)	.346 (4.31)	.193 (2.48)		.71	.073
July	.514	−.441 (−2.64)			−.142 (−2.22)	.292 (4.68)		.166 (2.49)	.76	.061

Note: Units in which the explanatory variables are measured are: *IPOC*, ratio of Eastern Canadian production to Eastern Canadian consumption with 1 occurring when the two are equal; *CCP*, 1 = 100 million bu.; *USCP*, 1 = 1 billion bu.; *WFGA*, 1 = 1 million tonnes.

these areas. The latter is relatively costly and tends to result in Ontario prices being bid up relative to the futures price.

Great Lake-St. Lawrence shipping is opened during March or April, resulting again in increased competition for the eastern Canadian market and a narrower basis. During the late spring and summer, Ontario prices have tended to increase relative to the futures price because Ontario's crop has not been sufficiently large to meet eastern Canada's demand during these months.

The resulting seasonal basis pattern is apparent in figure 2, which contains the average nearby Chatham basis for each month of crop years 1971–75. To account for this seasonality, and on the hypothesis that different factors affect the basis in different months, a separate equation was estimated for each month of the crop year. The results in table 1 tend to support this hypothesis. (As in figure 1, basis in figure 2 is calculated from the nearby future and is adjusted for exchange rates.)

Ratio of Eastern Canadian Corn Production to Consumption

This variable was included to account for competition in the eastern Canadian market between domestic and U.S. corn, as discussed in the previous section. As the ratio approaches or exceeds unity, domestic and imported corn would compete east of Montreal or on the export market and the Chatham basis would be bid down for the reasons explained earlier. Thus, the variable should be related inversely to the basis throughout the crop year.

The results are as expected. The ratio is significant in all months except November and December when harvest variables explain much of the basis variation (see below).

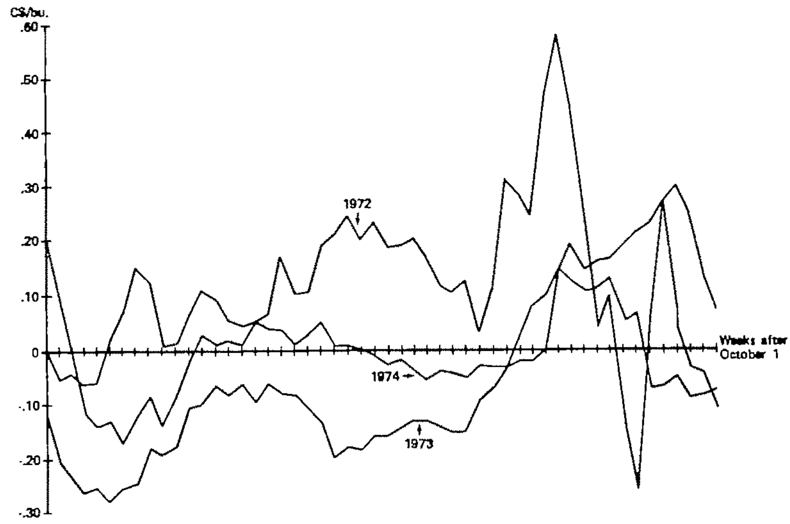
Canadian Corn Production

This variable was included because of the expected relationship between the size of the crop and storage charges in Ontario. The larger the crop, the greater the demand for storage; hence, the local basis would be expected to fall to cover increased storage costs.

The results are consistent with the expectation. The Canadian crop is a significant variable during the harvest period as would be anticipated because this is the period when demand for storage is greatest.

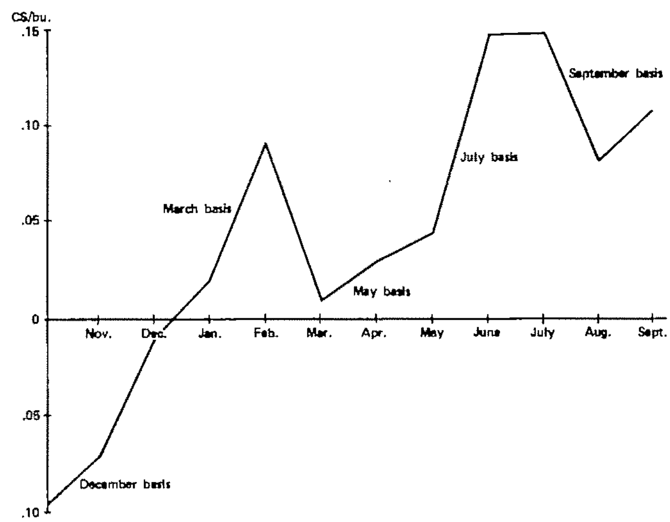
U.S. Corn Production

U.S. corn production is included for two reasons. First, the size of the crop could be a determinant of short hedging pressure at harvest time. A large U.S. crop would place downward pressure on futures prices. Second, a large U.S. crop would motivate shipping more corn through the Great Lakes-St. Lawrence system in the fall before the close of navigation. This, in turn, would increase the demand for transport and handling services during this period, thereby increasing the costs of these



Note: See footnote [2] for explanation of figure.

Figure 1. Weekly basis for corn, Chatham, Ontario, crop years Oct.–Sept. 1972, 1974, 1975



Note: See footnote [3] for explanation of figure.

Figure 2. Monthly corn basis, averaged over crop years 1971–75, Chatham, Ontario

services. Hence, the size of the U.S. crop is a proxy for the demand for these services. Both factors suggest that the size of the U.S. corn crop would be related directly to the Ontario basis during the fall.

Again, the analysis confirms the expectation as indicated by the coefficients for November and December in table 1.

Western Feed Grain Availability

Western feed grain availability is included as a proxy for Canadian Wheat Board and federal feed grain pricing policy. These policies have changed often and markedly during recent years and are therefore both unquantifiable and unpredictable. However, a measure of availability is included on the ground that competition from western feed grains should be expected to affect the eastern corn basis. Availability was measured initially as stocks of western feed grains in lakehead and eastern elevators. However, in initial runs, this variable was found to carry no statistical significance. This is likely because the data do not separate stocks intended for domestic and export markets.

As an alternative, actual movements of western feed grains to the domestic eastern market were used in the analysis. This variable is expected to be related inversely to the basis. The expectation is confirmed by the coefficients on the variable from May onward in table 1.

Dummy Variables

Dummy variable D72 was included for January through July of crop year 1972 (i.e., calendar year 1973) to account for an inversion in corn futures prices during this period. As a result, U.S. export prices apparently were based on the spot instead of the nearby futures price, and the Ontario basis showed substantial premia over the futures prices.

Dummy variable D73 was included for the months of November through June (except March) of crop year 1973. During that crop year, the Canadian Wheat Board established initial prices for Board grains at high levels. This led to the delivery of most board grains to the Canadian Wheat Board, which then exported them. As a result, there was little movement of western grains to the East and therefore a premium was bid on Canadian corn. In March 1974, when navigation opened, the premium disappeared, reflecting expected U.S. corn imports. However, little U.S. corn was imported until July; so the premium on Canadian corn reappeared from April through June.

Dummy variable D74 was included for July and August of crop year 1974. The 1974 corn crop in Canada was of record size. In the fall, trade sources believed Canada would be in a surplus position and, accordingly, exported a record 10 million bushels early in the crop year. Subsequently, it became apparent that domestic demand for corn had been underestimated and substantial amounts of U.S. corn were imported late in the crop year.

The results in table 1 indicate that the market aberrations each had considerable positive impact on the local basis, as expected.

Sensitivity of Basis Residual to the Explanatory Variables

It is of interest to show the sensitivity of basis to changes in the explanatory variables. While this normally would be done using elasticities, elasticities are of little meaning in this analysis because of the small magnitude of the dependent variables. Instead, the absolute change in basis associated with a 10% change from the mean in each explanatory variable is presented in table 2.

Data in table 2 indicate that basis residual is quite sensitive to most of the variables. Of the eight months for which the ratio variable (*IPOC*) is significant, a 10% change results in 3¢ per bushel or more change in basis in six months. Domestic corn consumption averaged about 110 million bushels per year over this period. Hence, the 10% change in *IPOC* represents approximately 8.5 million bushels in Canadian production.

The basis residual in November and December is quite sensitive to Canadian and U.S. corn production. The greater sensitivity implicit in the U.S. production variable is initially surprising; however, a 10% change in U.S. production is more than five times total Canadian production.

Basis residual for May through July is not particularly sensitive to western feed grain availability. However, during the sixteen years of the analysis, shipments of western feed grains to eastern Canada varied from virtually nil to 1.03 million tons. A change in shipments of 10% from the mean is only 72,000 tons; but year-to-year changes obviously can be far in excess of this.

Conclusions

The analysis suggests that a substantial amount of the variation in the southwestern Ontario basis is explained by variables reflecting local market conditions. During the fall months, the size of the Canadian and U.S. crops is the most important factor. During the winter, when the eastern Canadian market is essentially closed except to relatively costly rail access from the United States and

Table 2. Absolute Change in Basis Associated with a 10% Change in Each Explanatory Variable

		Change in Basis from a 10% Change in:[a]			
Month	Mean of Basis Residual	*IPOC*	*CCP*	*USCP*	*WFGA*
		($/bu)			
October	−.079	−.046			
November	−.077		−.027	.072	
December	−.044		−.020	.050	
January	−.022	−.035			
February	.099	−.037			
March	−.005	−.033			
April	.005	−.031			
May	.026	−.021			−.011
June	.071	−.016			−.013
July	.107	−.034			−.010

[a] Means of the explanatory variables are: *IPOC* = .76 = ratio of Canadian production to consumption; *CCP* = .86 = 86 mil. bu.; *USCP* = 5.7 bil. bu.; *WFGA* = .72 = 720 thousand tonnes.

western Canada, the only significant factor is the size of the Canadian crop relative to local demand. After navigation is reopened in the spring, both local production relative to demand and the availability of western feed grains have significant effects. The relative insensitivity of the variable representing western feed grains suggests that Canadian policy affecting western grains is not normally as significant a factor in determining Ontario corn prices as is often perceived in Canada. This inference must, however, be qualified by the difficulties in measurement of the variable and by the coefficients on *D*73 which suggest that events in western Canada are important in extreme circumstances.

That the basis for corn in southwestern Ontario adjusts to local market conditions as theory implies provides some reassurance about the market's pricing performance. However, the analysis does not purport to provide evidence on whether prices are optimum in any sense. From a practical standpoint, the analysis provides information that could be useful to local traders and hedgers in understanding the factors which affect the basis.

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References

Brennan, M. J. "The Supply of Storage." *Amer. Econ. Rev.* 47(1958):50–72.

Driscoll, J. L., and L. V. Blakley. *Expected Returns for Hedging Stored Wheat in Oklahoma.* Oklahoma State University Agr. Exp. Sta. Bull. B-677, Apr. 1970.

Gray, Roger W. "Price Effects of a Lack of Speculation." *Food Res. Inst. Stud.* 7(Suppl. 1967):117–94.

———. "The Characteristic Bias in Some Thin Futures Markets." *Food Res. Inst. Stud.* 1(1960):296–312.

Heifner, R. G. *The Gains from Basing Grain Storage Decisions on Cash-Futures Spreads in Michigan.* Michigan State University Exp. Sta. Quart. Bull., vol. 48, no. 4, May 1966.

———. *Hedging Potential in Grain Storage and Livestock Feeding.* USDA ERS Agr. Econ. Rep. No. 238, Jan. 1973.

Kenyon, David E., and Paul K. Blakely. *Alternative Basis Estimation Procedures and Hedging Strategies for Corn and Soybean Producers in Selected Virginia Markets.* Dep. Agr. Econ. Bull. AE18, Virginia Polytechnic Institute and State University, Sept. 1974.

Martin, Larry. *Commodity Futures Markets—Hedging Opportunities for Ontario Grain Corn and Soybean Producers.* School of Agr. Econ. & Extens. Educ. Bull. AE/73/12, University of Guelph, July 1973.

Martin, Larry, and Gary Storey. "Temporal Price Relationships in the Vancouver Rapeseed Futures Market and Their Implications to Farm Prices." *Can. J. Agr. Econ.* 23(1975):1–12.

Regli, P. *Pricing Corn in Ontario.* Ontario Ministry of Agriculture and Food Fact Sheet AGDEX 111/840, Ontario 1975.

Ward, Ronald W., and Frank A. Dasse. "Empirical Contributions to Basis Theory: The Case of Citrus Futures." *Amer. J. Agr. Econ.* 59(1977):71–80.

Weymar, Helmut. "The Supply of Storage Revisited." *Amer. Econ. Rev.* 56(1966):1226–34.

Working, H. "Theory of the Inverse Carrying Charge in Futures Markets." *J. Farm Econ.* 30(1948):1–28.

Revisiting the Advertising-Concentration Issue

Ronald W. Ward and Robert M. Behr

Increases in advertising efforts are reasonably well documented among most U.S. industries (Nelson, p. 43). Yet, the economic controversy relating to the causal linkage between advertising intensity and changing market structures is not settled. Advertising can represent a major barrier to entry by its role in achieving product differentiation. In contrast, advertising may enhance competition with the dissemination of information through competitive advertising. While the advertising issues are varied and complex, this paper will set forth additional empirical evidence showing the relationship between advertising intensity and changing industry structure. In particular, the intensity of advertising across industry levels of concentration will be addressed and reference will be given to the food industries.

Studies suggesting that advertising leads to increased concentration have at the best been mixed (Blair). The argument suggesting that the advertising intensity varies positively (or negatively) with concentration has been slightly more definitive. Schmalensee argued that as concentration increases and profits rise, the marginal unit of sales becomes more profitable and it pays more to advertise to capture these additional sales (Mann, p. 150). Strickland and Weiss developed a simultaneous equation model with one equation relating advertising intensity to concentration where both variables are endogenous. Their analyses show that little bias is evident when the advertising intensity equation is estimated as a single equation in contrast to the simultaneous equation results (p. 1116). Because the primary focus of this analysis is to gain a better understanding of changing advertising intensity, the relationship is estimated in a single equation framework relying on Strickland and Weiss's conclusions as to the degree of bias that may occur.

The basic arguments for concentration influencing advertising intensity are two. (*a*) With increased concentration, firms recognize their rival's advertising reaction curve and will thus decrease their advertising effort on the assumption that it only has a neutralizing effect on the rival's advertising. Or, (*b*) with increased concentration, firms will substitute nonprice competition via advertising for price competition. The second argument implies a positive association between advertising and concentration, while the first argument suggests a negative relationship. These effects in turn lead to the public policy dialogue concerning the net social benefits derived from price versus nonprice competition.

Advertising-Concentration Linkage

Dorfman-Steiner's studies of price and nonprice decisions provide a clear linkage establishing the static optimal advertising decision rule to be related to both price and nonprice decisions (Needham, p. 87; Ward, p. 500). If ϵ_a and ϵ_d are the firm's elasticities of advertising and demand, then $A/S = \epsilon_a/|\epsilon_d|$ according to the static rule where A is advertising expenditures and S is sales.

The current issue is how the advertising intensity (A/S) changes with industry concentration (C) and how concentration influences both ϵ_a and $|\epsilon_d|$. The advertising and concentration relationship obviously is confounded in the effect concentration has on both elasticities. If concentration leads to greater economies of scale to advertising and increased product differentiation (i.e., $\partial\epsilon_a/\partial C > 0$) and a corresponding reduction in substitutes (i.e., $\partial|\epsilon_d|/\partial C < 0$), then it always follows that advertising intensity will increase with concentration. The adjustments in ϵ_a and ϵ_d are not altogether clear, however.

The firm's advertising elasticity further has been shown to be related to the rival's advertising response (Needham, p. 85). Assuming that the industry structure is such that rival response is not apparent, then the arguments for a neutralizing and/or retaliatory advertising response are not relevant. However, as concentration increases anticipated rival response can not go unnoticed.

The concentration-intensity linkage is further confounded when one turns to the effects of concentration on the elasticity of demand. Price elasticity of demand is related to the rival's response, and this response is influenced by the level of concentration. With no rival response it is relatively easy to show that the firm's demand becomes less elastic with increased concentration. If increased rival response to firm price changes is anticipated, advertising will be substituted for price competition. However, as concentration increases, rival impact may be lessened and the need to substitute nonprice for price competition would be reduced.

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Table 1. Hypothesized Effects of Concentration on Advertising Intensity [$\partial(A/S)/\partial C$]

	$\partial\epsilon_a/\partial C$		
$\partial\lvert\epsilon_d\rvert/\partial C$	+	0	−
+	?	−	−
0	+	0	−
−	+	+	?

Note: The signs within the table follow from the relationship where $\partial(A/S)/\partial C = (1/\lvert\epsilon_d\rvert)[\partial\epsilon_a/\partial C - (A/S)(\partial\lvert\epsilon_d\rvert/\partial C)]$, as derived using the Dorfman-Steiner theorem.

The problem with hypothesizing the advertising-concentration relationship is illustrated in table 1, where the alternative signs for $\partial(A/S)/\partial C$ are shown. Given the difficulties in determining the signs from the effects of concentration on ϵ_a and ϵ_d, an alternative would be to estimate directly the relationship between advertising and concentration. The empirical results may then suggest the relative importance of ϵ_a and ϵ_d to the advertising-concentration issue.

Advertising-Concentration Model

The analysis from the above section indicates that the advertising-concentration relationship ultimately will depend on empirical models. To date, mixed results have been reported when estimating the model where $A/S = f(C)$ (Mann, pp. 142–56). While the theoretical problems cannot be compromised, many of the difficulties with previous studies can be related to model misspecification, incompleteness in data classification, and inappropriateness of the estimation techniques. Recent studies by Ornstein have addressed the empirical problems of relating advertising and concentration. His studies show a positive but statistically weak relationship between concentration and advertising. Additional studies by Brush provide support for the validity of the data series developed by Ornstein.

For the present problem, concentration and advertising data are taken from the SIC for four-digit industries. The value of shipments of the top four firms relative to total shipments is used as a measure of concentration and the advertising data from Ornstein's study are used (p. 45). Shepherd provided an adjusted data series for the 1966 four-firm concentration ratios for the purpose of correcting what was believed to be a problem with the data similar to that used by Ornstein. Brush's studies of Ornstein's models using the corrected data led him to conclude that "correction of errors in the official Census concentration ratios has had little effect on the statistical estimation of the advertising concentration relationship . . ." (p. 985). For this reason, the initial data reported by Ornstein will be used. The advertising and concentration levels are measured across industries and the SIC codes are classified according to consumer versus producer goods, and durable versus nondurable goods. Many of the consumer nondurables are food industries. The cross-sectional data of four-digit industries are recorded over the years of 1947, 1963, and 1967.

Both Ornstein's and Strickland and Weiss' models are specified such that the intensity may decline with high levels of concentration. Ornstein's results supporting a declining intensity are statistically weak. Whereas, while Strickland and Weiss' statistical results are strong, there appears to be some difficulty with changes in the signs of their advertising relationship as they change the specification of their model (p. 1116). In the current model, the specification facilitates a nonlinear relationship initially assuming that the effect of concentration at least approaches some upper limit. The alternative where the intensity may decline is considered. The asymptotic function follows as the adjustments in ϵ_a and $\lvert\epsilon_d\rvert$ can be expected to approach limits such that $\lim \partial\epsilon_a/\partial C = 0$ and $\lim \partial\lvert\epsilon_d\rvert/\partial C = 0$.

The response to concentration may differ across industries simply because of the differences in both advertising and price elasticities for particular product categories. Finally, there may be reason to suspect that advertising intensity has increased since 1947 as a partial result from increased availability of advertising media. Each of the adjustments above have been ignored in most model specifications or at least have been treated in separate models.

Using the above arguments, the model specification below can be used to test the advertising-concentration relationship.

$$\text{(1)} \qquad \frac{A}{S} = \exp^{\{\tau_0 + \tau_1/C + \mu\}},$$

where

$\tau_0 = \beta_0 + \beta_1 PRO + \beta_2 DUR + \beta_3 T_1 + \beta_4 T_2$, and
$\tau_1 = \alpha_0 + \alpha_1 PRO + \alpha_2 DUR + \alpha_3 T_1 + \alpha_4 T_2$, and
A/S is the advertising-sales ratio (i.e., $0 \le A/S \le 100$);[1] C is the four-digit, SIC industry classification ($0 \le C \le 100$); PRO is the type of good (-1, producer; $+1$, consumer); DUR is a perishability measure (-1, durable; $+1$, nondurable); T is year where ($T_1 = 1$, $T_2 = 0$, for 1947; $T_1 = 0$, $T_2 = 1$, for 1963; $T_1 = 0$, $T_2 = 0$, for 1967). Note that τ_0 and τ_1 include the effects of PRO, DUR, and T, and both the level of advertising intensity and the response of advertising intensity to levels of concentration. Finally, the relationship has the asymptotic property where $\lim_{C \to 100} A/S = \exp^{\{\tau_0 + .01\tau_1\}}$, and the limit will change directly depending on the time and product classifications.

Equation (1) is estimated over a sample of 914 observations drawn from the Census of Manufac-

[1] Advertising was not deflated over the three time periods because both sales and advertising are influenced by inflation and the effects of inflation should be netted out in the intensity ratio.

turing (Ornstein, pp. 74–85). Industries differ within the four-digit classification and, hence, the effect of concentration may vary across industries. Therefore, in addition to the classifications by type and perishability, the concentration parameter may have a random component giving $\alpha_0 + \nu$, where ν is an error term having the traditional properties. The dummy variables were defined such that both β_0 and α_0 represent some average effect, and the differences in type are calculated as some adjustment to this average. The randomness in the concentration coefficient is calculated only for this average and not each parameter in (1). The error in (1) is now $\mu + \nu(1/C)$, and the variance is $\sigma_\mu^2(1 + \rho/C^2)$, letting $\rho = \sigma_\nu^2/\sigma_\mu^2$ (Maddala, p. 390).

Equation (1) is estimated by maximizing the concentration likelihood function over values of ρ and the results are shown in table 2. The random coefficient model adds little to the analysis since the maximum value of the likelihood function occurs when $\rho = 0$. Pooling the data across four-digit concentration levels after explicitly accounting for time, type, and perishability does not create estimation problems that might have been expected initially, given the diverse nature of the industries included in the sample.

The statistical results shown in table 2 are probably the strongest to date in support of the relationship between advertising intensity and concentration. The t-values for α_0 and α_1 show the relationship to be significant at the 99% confidence level. Furthermore, response among consumer industries is statistically different from those producer goods industries. This difference is of particular interest since much of agricultural manufacturing relates to consumer goods in the form of food and kindred products. No statistical difference between durable and nondurable goods is evident. Finally the coefficient of determination shows that 39% of the

Table 2. ML Estimates of the Advertising-Concentration Relationship with $\rho = 0$.

		Parameter Estimates	t-Statistic
Intercept	β_0	.47938	4.4040
PRO	β_1	.94502	13.1690
DUR	β_2	.05811	.8742
T_1	β_3	−.95036	−6.6267
T_2	β_4	−.10597	− .8016
$1/C$	α_0	−10.20310	−4.0863
PRO/C	α_1	−7.14310	−4.1137
DUR/C	α_2	−1.14322	−0.7183
T_1/C	α_3	2.82010	.8711
T_2/C	α_4	1.51140	.5678
		R^2	= .3982
		$F(9,904)$	= 59.82
		OBS	= 914

Note: The model is estimated as a log-reciprocal equation with the dependent variable A/S (see eq. 1). The concentrated likelihood function was maximized when $\rho = 0$.

variation in advertising intensity has been explained. Other factors, some of which are likely unique to each industry, must be addressed in order to further explain intensity. What is important at this stage in the advertising-concentration dialogue is that the relationship has been established. An alternative to model (1), where substantial concentration could eventually lead to less advertising, has been specified as

$$\frac{A}{S} = \exp^{(\tau_0 + \tau_1/C + \mu)} C^{\tau_2}. \tag{2}$$

If $\tau_2 < 0$ and $\tau_1 < 0$, advertising intensity could both increase and decrease with C. This function has the property that $A/S \geq 0$, whereas many of the polynomial functions reported could yield $A/S < 0$. This model was estimated and the empirical results failed to yield any improvements over those in table 2, thus adding more credence to the asymptotic function (Ornstein, Strickland and Weiss).

Product Classifications

As suggested above, a large number of the nondurable industries relate to food and kindred industries. Attempts, however, explicitly to separate out the advertising intensity relationship for this subset of four-digit industries have not proven significant. Rather, the broad product class of consumer versus producer goods is the most important distinction. This would be expected because buyers of producer goods should be less susceptible to product image created by advertising (Mann, p. 139; Strickland and Weiss, p. 1111). Producer products are purchased in sufficient volume and frequency that the alternatives can be appraised. Also, consumer goods are generally more differentiable. Generally, the number of potential buyers are less for the producer versus consumer goods and, hence, the cost of reaching the buyers of producer goods should be less.

When comparing the effects of concentration on consumer versus producer goods, one would expect intuitively the elasticity of demand to change less among those producer versus consumer goods because the product is judged primarily on its characteristics and less on image. Hence, the significance of α_1 in table 2 seems plausible from a theoretical perspective. We are still left with the issue of what happens to ϵ_a for both product categories. If consumers are more susceptible to the image effect in consumer goods as suggested by Mann, then $\partial\epsilon_a/\partial C$ for consumer goods is likely to exceed that of producer goods and the advertising intensity for consumer goods should exceed that of producer goods.

The relationship between producer and consumer goods is illustrated in figure 1 for the nondurable category. Obviously, advertising plays a small role in the very low concentrated industries regardless of the product category. As concentration in-

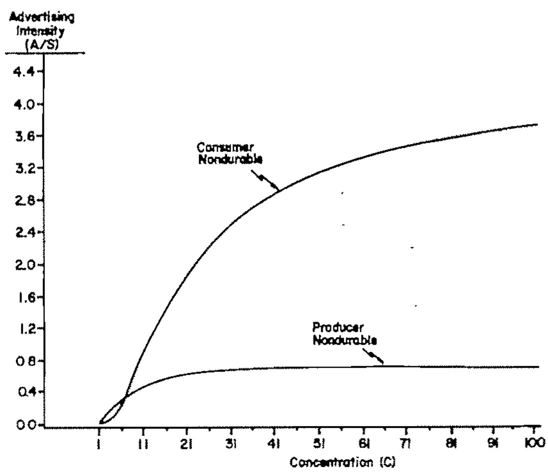

Figure 1. Advertising intensity-concentration relationship for consumer and producer nondurables (1967)

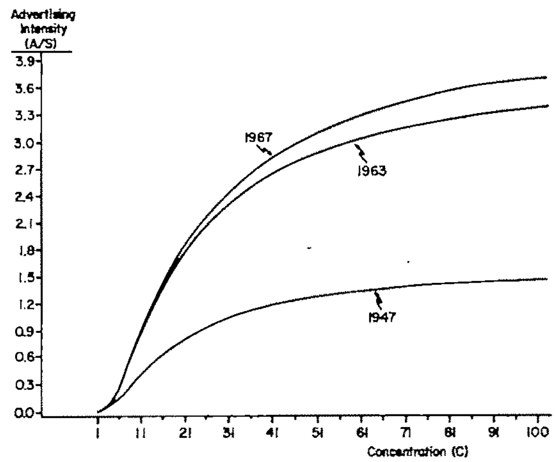

Figure 2. Advertising intensity-concentration relationship for consumer nondurables across time (1947, 1963, 1967)

creases, the advertisng intensity rises rapidly for both goods. Beyond the 20% level very little increase among producer goods industries is evident; whereas, advertising continues to rise rapidly for the consumer goods. The durable category is not shown since the relationship does not differ significantly from that shown in figure 1.

Adjustment over Time

Figure 2 illustrates the adjustments that have taken place since 1947, and the increased use of advertising for each concentration level is most apparent. Advertising intensity has increased and one important consideration is how much increase would have occurred without any change in concentration. Increased intensity with more concentration suggests substitution of nonprice for price competition. Increased intensity over time holding concentration levels fixed does not preclude the substitution for price competition, but it does indicate that greater effort to establish information flows has occurred.

The changing slopes of each response in figure 2 is of special importance in that they clearly show that the effects of structural change on advertising intensity have increased since 1947. The rate of increase in advertising intensity to increases in concentration nearly doubled between 1947–67. While advertising has become more important to concentrated industries, the results still do not totally show how much of this change represented substitution for price competition. A useful extension of the analysis would be to explore an index of price changes among the same industries included in this study.

Figure 3 is useful for depicting the adjustment that has occurred since 1947, holding all concentration levels fixed at their 1947 values. The vertical axis gives the estimated percentage adjustments that would have occurred due to the time alone and is calculated as

$$(3)\quad \frac{(A/S)_{67}}{(A/S)_{47}} - 1 = \exp^{-\left\{\beta_3 + \frac{\alpha_3}{C_{47}}\right\}} - 1,$$

where $C_{47} = C_{67}$ is assumed [see eq. (1)].

Advertising intensity would have declined over time for those industries with concentration under 2%. Whereas for industries having initial concen-

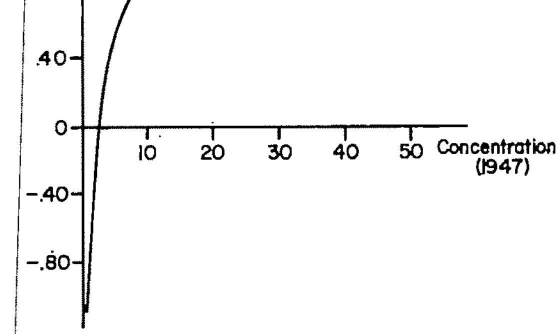

Figure 3. Relative change in advertising intensity from 1947 to 1967 holding concentration levels fixed (see eq. 3)

Houck, J. P. "An Approach to Specifying and Estimating Nonreversible Functions." *Amer. J. Agr. Econ.* 59(1977):570–72.
Pierce, D. A. "Relationships—and the Lack Thereof—between Economic Time Series, with Special Reference to Money and Interest Rates." *J. Amer. Statist. Assoc.* 72(1977):11–23.
Popkin, J. "Consumer and Wholesale Prices in a Model of Price Behavior by Stage of Processing." *Rev. Econ. and Statist.* 56(1974):486–501.
Samuelson, P. A. *Foundations of Economic Analysis.* Cambridge, Mass.: Harvard University Press, 1961.
Sims, C. "Money, Income and Causality." *Amer. Econ. Rev.* 62(1972):540–52.
Tweeten, L., and L. Quance. "Positivistic Measures of Aggregate Supply Elasticities: Some New Approaches." *Amer. J. Agr. Econ.* 51(1969):342–52.
Wolffram, R. "Positivistic Measures of Aggregate Supply Elasticities: Some New Approaches—Some Critical Notes." *Amer. J. Agr. Econ.* 53(1971):356–59.

Appendix A
Wholesale-Retail Food Price Relationships

Commodity	*WP*	*WP*-1	*WP*-2	*WP*-3	*WP*-4	*ULC*	*UR*	$\bar{R}^2$/ *D.W.*/*p*	*C/W*
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Bread	.16	.0026					−.04	.847	2.4
	17.2	2.8					3.3	1.84	−1.4
	.73	.012					.009	.942	
Sugar	.274	.131						.834	53.5
	12.6	28.3						2.12	−2.9
	.47	.22						.751	
Soft drinks	.77	.254	−.25			1.44	−.44	.999	11.8
	7.1	1.5	2.3			16.9	2.5	.60	5.3
	.77	.25	.25			.31	.02	.965	
Potatoes	.145	.201	.092	.006		1.08	−2.79	.916	17.3
	4.7	4.7	2.1	.2		6.1	4.1	.60	2.8
	.22	.30	.14	.01		.29	.16	0.0	
Apples	.034	.036	.007			.717	−1.28	.979	3.1
	2.8	2.9	.5			22.8	6.7	.43	.5
	.16	.17	.03			.77	.29	.082	
Oranges	.072	.082	−.002	.002	−.046	.229		.411	.5
	4.5	5.0	.11	.12	2.9	5.6		1.50	−3.0
	.098	.112	.003	.003	.06	.06		.806	
Canned tomatoes	.029	.016				.026	−.028	.920	3.1
	4.8	8.9				4.9	2.2	1.53	−4.3
	.13	.07				.03	.007	.91	
Rice	.030	.038	−.011	−.014				.745	1.3
	6.7	8.2	1.6	3.2				1.51	11.6
	.14	.17	.05	.06				.930	
Lettuce	.072	.009	−.040	−.021		.065	−.109	.994	1.8
	8.2	1.0	4.3	2.3		1.0	.40	2.97	1.4
	.26	.03	.15	.08		.05	.02	−.262	
Vegetable shortening	.241	.034						.423	5.4
	7.3	7.0						1.63	−4.4
	.28	.04						.957	
Margarine	.067	.141	−.089	−.026	−.016	.0047		.861	4.0
	8.6	17.9	7.6	2.1	1.3	.50		1.72	1.7
	.24	.50	.32	.09	.05	.003		.958	
Milk	.23	.045				.055		.870	1.7
	6.9	.50				3.0		1.08	−6.3
	.42	.008				.024		.97	

Appendix A
Wholesale-Retail Food Price Relationships

Commodity	*WP*	*WP*-1	*WP*-2	*WP*-3	*WP*-4	*ULC*	*UR*	$\bar{R}^2$/ *D.W.*/ρ	*C/W*
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Eggs	.195	.168	.047	−.026		.23		.966	1.8
	16.2	11.3	3.1	2.2		8.2		1.50	−1.5
	.40	.35	.10	.05		.09		0.0	
Beef	.307	.159	−.08	−.066	.046	.078		.882	3.9
	18.2	8.9	2.9	2.4	1.8	1.8		2.05	1.7
	.37	.19	.09	.08	.05	.02		.867	
Pork	.33	.07					−.224	.927	2.5
	24.0	9.4					2.2	1.75	2.7
	.50	.11					.015	.811	
Chicken	.217	.047	−.002	.016	.040	.063		.960	1.2
	15.7	2.6	.10	1.0	2.8	1.8		1.86	.6
	.58	.12	.006	.04	.11	.035		0.0	
Butter	.164	.268	.231			.560		.999	7.5
	5.8	6.8	8.2			21.6		.75	10.4
	.19	.31	.27			.16		.664	
Salad oil	.164	.193	−.047					.975	1.3
	8.0	7.7	2.1					1.61	−1.3
	.31	.36	.09					.618	
Fresh orange juice	.026	.005	.013			.07		.530	10.1
	2.4	.30	1.3			8.9		1.57	1.1
	.07	.01	.04			.40		.884	
Fresh tomatoes	.042	.043	.055					.91	6.3
	2.7	2.7	3.5					.14	1.0
	.14	.14	.18					.72	
Chocolate bars	−.072	.348	.112			4.21		.991	2.8
	.30	1.4	7.0			9.1		.12	−4.9
	.07	.33	.12			.85		.961	
Frozen french fries	.02	.02	.10			.19	−.038	.861	1.8
	.80	.60	4.0			1.9	.90	.19	−5.0
	.14	.14	.73			.05	.04	0.0	

Note: Column (1) Commodity; Column (2)–(6) Regression coefficient, *t*-value and elasticity, respectively, for current and lagged wholesale prices (*WP*); Column (7) Regression coefficient, *t*-value and elasticity for unit labor costs in retail food stores; Column (8) Regression coefficient, *t*-value and elasticity for seasonally adjusted unemployment rate; Column (9) $\bar{R}^2$, Durbin-Watson statistic, and autocorrelation coefficient; and Column (10) *F*-statistic for Chow structural change test for 1975–1 to 1976–12 period and *t*-value for asymmetry test described in text.

Evaluating the Effects of P.L. 480 Wheat Imports on Brazil's Grain Sector

Lana L. Hall

Econometric analysis of the grain sector of Brazil shows that P.L. 480 wheat imports have had a positive impact on grain production. This was due primarily to government wheat import and domestic price support programs whereby revenues gained from wheat imports may be used to support domestic grain producers. The positive production impact must, however, be balanced against the negative effects of P.L. 480 on commercial wheat imports and the potential disruptions of world wheat markets.

Key words: Brazil, multiplier analysis, P.L. 480, wheat.

Although the United States has reduced its participation in food aid since 1972, under the P.L. 480 program, food aid continues to be an important foreign policy tool. In addition to sales at concessional terms under Title I of the P.L. 480 program, the United States contributes to the goals of the 1974 World Food Conference by distributing annually a minimum of 1.3 million tons of food assistance in the form of grants, under Title II of the P.L. 480 program (USDA 1977, p. 5). Other donor countries, such as those in the European Economic Community (EEC), also are increasing their participation in food aid programs. Increasingly, however, the emphasis is on using food aid positively for agricultural development purposes and avoiding detrimental effects on a country's agriculture caused by the introduction of food aid. For this reason, it is important to evaluate the experiences of the P.L. 480 program of the United States in regard to its actual contributions to agricultural development. Toward doing so, this paper attempts to analyze the effects of P.L. 480 Title I wheat imports on Brazil's grain sector.

Brazil's experiences with the P.L. 480 program provides a good case study. First, many of the previous analyses of the effects of P.L. 480 imports on specific recipients have been made for Asian countries, particularly for India (see Blandford and von Plocki; Hatti; Mann; Rogers, Srivastava, Heady; Seevers; and Sen). Brazil's imports of P.L. 480 wheat have, however, been considerable. Total wheat imports, commercial plus P.L. 480, averaged two and one-half times greater than domestic production over the period 1955–70, and P.L. 480, as a percentage of total wheat imports, increased from 24% in 1955–59, to 47% in 1960–64, then decreased to 16% in 1965–69. P.L. 480 imports averaged 28% of total wheat imports and 70% of domestic production from the time the program began in 1954 to 1970, when the P.L. 480 wheat shipments to Brazil ceased.

Second, the institutional arrangement under which Brazil imports wheat and the extensive government intervention in Brazil's grain sector are interesting for understanding possibilities of using food aid for agricultural development purposes. Such intervention also brings out the necessity of specifically including government policies towards the production and consumption of grains and policies affecting the use and distribution of food aid. For example, Rogers, Srivastava, and Heady, in evaluating the effects of P.L. 480 grain imports on India's grain sector, allow for the possibility of distribution of food aid through a lower-priced concessional market. They find that the impact of food aid on prices and production in India is one-tenth the impact shown when not allowing for the possibility.

In addition to allowing for variation in such factors as government pricing and distribution policies when food aid is introduced into an economy, interrelationships in production and

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consumption also should be included. This is difficult when all grains are aggregated into a single commodity. The present study includes these interrelationships in production and consumption among four major grains as well as the government policies affecting the production and consumption of these grains. An econometric model including these interrelationships and reflecting the grain-marketing strategies of the Brazilian government is developed, and a multiplier analysis is used to quantify the effects of P.L. 480 Title I wheat imports on grain prices, production, and consumption.

Grain-Pricing Policies in Brazil

The government intervenes extensively in grain pricing in Brazil, particularly for wheat, guaranteeing minimum prices to producers, setting consumer price ceilings and trade restrictions. Since 1952, the Marketing Department for National Wheat (CITRIN) has conducted all purchases and sales of domestic wheat and has been the sole importer and supplier to domestic mills. In 1962, CITRIN became the sole purchaser, at the established support price, of domestic wheat. The imported and domestic wheat is sold to the mills at a uniform price, a price set such that the processed products fit within the purchasing power of the average urban consumer. The price at which the government sells imported and domestic wheat to the millers is generally higher than that which the government paid for the imported wheat, but lower than the established support price which the government pays to the domestic wheat producer (Knight, p. 89; Paiva, Schattan, Freitas, p. 141).

Given a low enough price for imported wheat, there exists an opportunity for the government, through CITRIN, to make revenues from the sale of imported wheat and utilize the revenues gained for subsidizing domestic producers. For example, in figure 1, where P_1 is the price to the mills of domestic and imported wheat, P_2 is the price paid by the government for imported wheat, and P^* the established producer support price, revenues $ABCD$ can be made from selling amount Q_1Q_2 of imported wheat to the mills at price P_1, revenues which can be used to cover the subsidy of P_1 AJP^* paid to producers. This subsidy is the difference between the price, P^*,

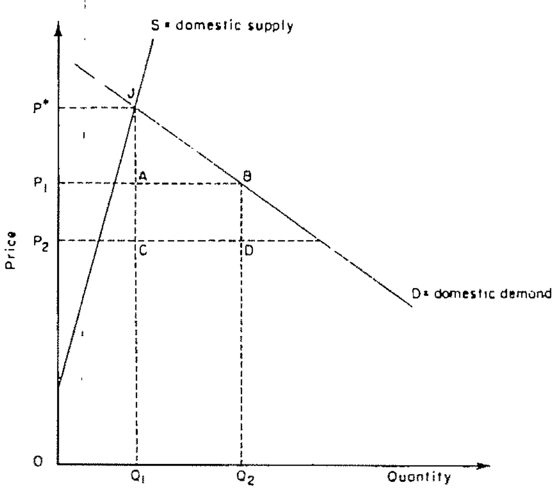

Figure 1. Wheat import revenues and production subsidy costs

paid by the government for the domestic production and the price, P_1, received by the government from its resale. The lower the per unit price paid by the government for imported wheat, the greater the revenues that can be made from importing a given amount of wheat and reselling it at a set price (such as P_1 in fig. 1) to the mills. If the revenues obtained are used to subsidize domestic producers by increasing price supports in, for example, the following time period, the greater the revenues, the greater can be the subsidy to domestic producers. Alternatively, the lower the import price of wheat, the lower can be the price at which the government sells the wheat to the mills (and given constant marketing margins, the lower the price to the ultimate consumer of wheat) and still maintains sufficient revenues to cover the cost of the domestic production subsidy at an established support price (such as P^* in fig. 1). Because the price regulation implied by such strategies is the result of a political balancing of producer and consumer interests, the outcome is not completely determinate, but will vary from year to year.

By importing a greater proportion of wheat under P.L. 480, the average price of wheat imports is considerably decreased. (See Adams et al., Berlage, Dudley and Sandilands, Knight). Government revenues may be increased correspondingly and used in the ways described above. As a rough indication of the extent to which it would have been possible for the Brazilian government to have used the revenues obtained from importing commercial and P.L. 480 wheat, reselling it to the mills at a generally higher price, to cover the costs

of the subsidy to domestic producers (costs incurred by buying domestic wheat at the established price support, and reselling it at a generally lower price to the mills), these revenues were calculated over the period 1955–70. The revenues were calculated in local currency, evaluated at the prevailing exchange rate, assuming (*a*) that the P.L. 480 component of total imports was a pure grant and (*b*) the full c.i.f. price was paid for the P.L. 480 component. Under (*a*), the revenues obtained during each year would have been sufficient to cover the costs of the domestic price support program in twelve of the years from 1955–70, but under assumption (*b*), i.e., no grant element in the P.L. 480 imports, the revenues would have covered those costs in only four of the years, indicating the importance of P.L. 480 in the use of import revenues to support wheat prices.

Econometric Model of Brazil's Grain Sector

To evaluate the effects of P.L. 480 wheat imports on Brazil's grain sector, a simultaneous equation model, incorporating supply and demand relationships for wheat, corn, rice, and soybeans, was formulated, using as a basis the marketing and pricing strategies discussed above. The structural equations of the model, for each grain i, wheat, corn, rice, and soybeans, are

$$(1)\quad A_t^i = f^i(A_{t-1}^i, P_{t-1}^i, P_{t-1}^j, FP_{t-1}, CPI_{t-1}, TR),$$

$$(2)\quad QS_t^i = A_t^i Y_t^i,$$

$$(3)\quad PCQD_t^i = f^i(P_t^i, P_t^j, PCInc, CPI_t),$$

$$(4)\quad PCQD_t^i = \frac{QD_t^i}{N_t}, \text{ and}$$

$$(5)\quad QD_t^i = QS_t^i + M_t^i - Ex_t^i,$$

where t refers to the time period; A^i is area harvested of grain i, in 1,000 hectares (a constant relationship between planted and harvested hectarages was assumed); P^i, the price of grain i, cruzerios per metric ton; P^j, the price of substitute or complementary grain(s) j, cruzerios per metric ton; FP, the price for fertilizer, cruzeiros per metric ton; CPI, the consumer price index, 1963 = 100; Tr, the time trend; QS^i, the total domestic production of grain i, in 1,000 metric tons; Y^i, the average "yield" of grain i, metric tons per hectare (total quantity supplied divided by area harvested); $PCQD^i$, the per capita consumption of grain i, kilograms per capita; $PCInc$, the per capita income, cruzeiros per capita; QD^i, the total consumption of grain i, 1,000 metric tons; N, the total population, millions; M^i, the total commercial imports of grain i, 1,000 metric tons; and E^i, the total exports of grain i, 1,000 metric tons.

Because the current year's wheat support price, the price at which the government will purchase the domestic wheat crop, is set in advance of the planting and harvesting seasons, the support price set for year t would be expected to influence planting decisions in year t. Therefore, in equation (1), where i is wheat, P_{t-1}^i is P^{*w}_t, the domestic support price for wheat in year t.[1] Also, where j is wheat in equation (1), P_{t-1}^j is P^{*w}_t, that is, the current year's wheat support price in year t also influences hectarage decisions in year t for complementary or substitute grains. Lagged fertilizer prices were included as an indication of expectations regarding input prices.

Although minimum prices for rice, corn, and soybeans also have been set by the government, through the Commission for Production Financing (Comissao de Financiamento da Producao, or CFP), these prices cannot be said to have been relevant for production decisions during the time period studied. Minimum prices were usually below market prices and there was limited CFP participation in the market with few purchases exceeding 10% (Paiva, Schattan, Freitas, pp. 150–51). Minimum prices for grains other than wheat then were not used in the hectarage equations.

Where i is wheat in the demand equation (3), P^i was replaced by $\bar{P}^w$, the price at which the government sells the domestic and imported wheat to the mills. Similarly, where j is wheat, P^j is $\bar{P}^w$. Lack of reliable data prevented the demand for grains being expressed as final demands, such as for bread, corn products, etc. Retail demand responses can be generated, however, given constant margin assumptions. (See Foote, pp. 203–04).

All of the price variables are expressed in nominal terms. Leamer and Stern (pp. 45–47) argue that because the absence of money illusion is only a postulate and not a necessary description of reality, the absence of money

[1] Wheat support prices are from Brazilian government *Portarias*, or official decrees, issued closest to harvest date and are based on cost of production plus a profit margin considered sufficient to encourage the desired annual production increase.

illusion is too strong a proposition to be known a priori and imposed on the data. The coefficient on the undeflated price variable may be interpreted as the response of quantity demanded (or supplied) holding all other prices, the consumer price index (CPI), and incomes constant. Where price expectations, represented by lagged prices, were determinants of hectarage decisions, lagged CPI also was used for consistency and may be interpreted as a variable indicating expectations regarding inflation and affecting decisions accordingly.

In addition to the above set of equations (1) through (5), two equations pertaining only to wheat were added:

$$(6) \quad M_t^w = f^w(QS_t^w, P.L.\ 480_t^w, FXR_t, \bar{P}_t^w, CPI_t, Tr), \text{ and}$$

$$(7) \quad P^{*w}_{t+1} = f^w(M_t^w, P.L.\ 480_t^w, IP_t^w, CPI_t, Tr),$$

where M^w is quantity of commercially imported wheat, 1,000 metric tons; $P.L.\ 480^w$ is quantity of P.L. 480 wheat imported, 1,000 metric tons; FXR, foreign exchange reserves, millions of U.S. dollars; IP^w, international price of wheat, U.S. dollars per metric ton, and other variables are as defined above. In addition, $P.L.\ 480_t^w$ was added to the right-hand side of identity (5) for when i is wheat. Unfortunately, stocks could not be included in the model because of data availability.

The basic explanatory variables for the commercial wheat imports equation are suggested by the theory of demand in which the quantity demanded of a good depends on income, own price, and prices of other commodities. If imports and domestic goods are perfect substitutes, as may be approximately supposed for wheat, domestic supply also would be expected to influence directly imports and should be added to import demand. The level of foreign exchange reserves may be particularly relevant to a developing country's decision to import, especially if it is the government which controls imports, as in Brazil. It is likely that imports respond more to foreign exchange availability than to income levels (Leamer and Stern, pp. 15–16) or to the international price. For this reason and because in preliminary ordinary least squares (OLS) estimation the international price of wheat was found to be insignificant,[2] the reserve levels are entered as a determinant of import demand in place of international price and income levels.

Because of the government's control over wheat imports, whereby the imported wheat is sold to the mills at a set price, the mill price, $\bar{P}^w$, is also a determinant of commercial imports. Because of possible substitutions of P.L. 480 for commercial wheat and the role of P.L. 480 in lowering the total cost of wheat imports, the quantity of P.L. 480 wheat imported also determines commercial imports. P.L. 480 is treated as an exogenous variable because the quantity of P.L. 480 wheat to be imported is agreed upon a considerable length of time before actual importation.

The wheat support price equation (7) is based upon the fact that the same government agency sets support prices to wheat producers, importing and reselling imported wheat at a predetermined price to mills, a price usually higher than that paid by the government agency for the imported wheat. As discussed above, the revenues gained by doing so can be used to subsidize domestic wheat producers through higher price supports and the wheat support price is made a function of the determinants of these revenues. The support price in time $t + 1$ is made a function of revenues gained in time t because it is unlikely that the domestic supply schedule is known with great enough accuracy to enable the government to set a price support in time t (determining thereby domestic production and the quantity of imports needed) such that any import revenues made would be sufficient to cover the costs of buying the domestic production at that price support. P^{*w}_{t+1} then is made a function of the amount of commercial wheat imported in time t, the price at which the commercial imports were obtained, and the amount of P.L. 480 wheat imported, since the greater the amount of P.L. 480 in total imports, the lower the total cost of imports and the greater the revenues.

Data Sources and Measurement

Production, area harvested, and yield are from Brazil, Fundacao Instituto Brasileiro de Geografia e Estatistica (FIBGE) and Subsecretaria

[2] $$M_t^w = \underset{(7.20)}{2313.86} - \underset{(6.09)}{.88}\ QS_t^w - \underset{(6.45)}{.82}\ P.L.\ 480_t^w + \underset{(.40)}{.06}\ FXR + \underset{(1.51)}{1.00}\ \bar{P}_t^w + \underset{(.45)}{.49}\ CPI_t + \underset{(.03)}{.13}\ IP_t^w.$$

$R^2 = .93$

t-ratios in parentheses.

de Planejamento e Orcamento (SUPLAN), as are exports and imports and consumption, supplemented with data from the Food and Agriculture Organization (FAO) production and trade yearbooks, and USDA *Reference Tables* FR1-76 and FG9-76 (1976a, b). P.L. 480 shipments of wheat are from U.S. Department of Agriculture, Title I, Public Law 480, and include sales for local currency credit, dollar credit, and convertible local currency credit. Wheat flour was not included in the wheat imports data. Per capita figures were obtained using midyear estimates of population from the International Monetary Fund (IMF).

The support prices for domestically produced wheat are from the Brazilian government *Portarias*, or official decrees, issued closest to harvest data. From 1954–64, the prices are from Brazil, Ministerio da Agricultura and from 1965, are from Brazil, Superintendencia Nacional de Abastecimento. The support price issued for production year 1965–66, for example, refers to the quantity produced in 1966.

The prices paid by the mills for domestic and imported wheat were obtained from government *Portarias*, in which, for example, the 1966 price refers to 1966 consumption figures, and were also obtained from value of production (at farm level) data from FIBGE and SUPLAN, as were the prices for corn, rice, and soybeans. 1974 and 1975 prices for corn and rice are from Brazil, Centro de Estudos Agricolas.

Fertilizer prices are average prices paid in the state of São Paulo, weighted by apparent consumption of nitrogen, phosphate, and potassium fertilizers, from the Instituto de Economia Agricola. The consumer price index, 1963 = 100, is for period averages for the city of Rio de Janeiro, calculated by the Getulio Vargas Foundation, published by IMF, as were foreign exchange reserves of the Bank of Brazil. The international price of wheat used is the FOB Gulf, U.S. No. 2 hard winter, ordinary protein price, from the International Wheat Council.

Estimation

In the above system of equations (1)–(7), there are a total of twenty-two endogenous and twenty-eight exogenous variables, the endogenous variables being for each grain i: A_t^i, QS_t^i, $PCQD_t^i$, P_t^i (where i is wheat, P_t^i is $\bar{P}^w_t$), QD_t^i and, where i is wheat: M_t^w and P^{*w}_{t+1}. The exogenous variables for each grain i are: A_{t-1}^i, Y_t^i, and P_{t-1}^i (or P^{*w}_t, where i is wheat), in addition to FP_{t-1}, CPI_t, IP_t^w, CPI_{t-1}, $PCInc_t$, N_t, $P.L.\ 480_t^w$, FXR, Inc_t, and Tr, and, for when i is not wheat, M_t^i and Ex_t^i.

A stochastic disturbance term was added to all equations, but the identities and the model was estimated over the period 1952–75. Because of the recursive nature of the equations, the hectarage equations and the wheat price support equation for year $t + 1$ could be estimated consistently by OLS. The demand equations and the commercial wheat import equation were estimated by two-stage least squares (TSLS). From the statistical estimation of the model, the reduced form of the system was obtained and multiplier analysis performed.

Validation

To validate the model, from the reduced form, the model was simulated over a fifteen-year time period from the year 1952, and predicted values for wheat production and wheat imports were compared with observed values, although there are methodological difficulties (discussed in Day and Singh) in arriving at proper evaluation criteria. Predicted values closely followed the trends of actual values. Deviations of predicted from actual values averaged less than 21% for wheat production, the most serious deviations being overrepresentations of about 45%, for the years 1958 and 1966. For commercial imports, deviations of predicted from actual values averaged 18%, the most serious being an underrepresentation of 50% in 1964. When it is considered how much variation in wheat production and imports the model had to explain, the average deviations are seen to be moderate.

Results

The results of the hectarage equations estimated by OLS are shown below, with t-ratios in parentheses

$$\begin{aligned} A_t^w = {} & \underset{(2.37)}{531.2001} + \underset{(4.65)}{.7907}\, A_{t-1}^w \\ & + \underset{(2.86)}{6.2281}\, P^{*w}_t - \underset{(2.84)}{3.8054}\, FP_{t-1} \\ & - \underset{(1.33)}{.8117}\, CPI_{t-1} - \underset{(2.88)}{43.7894}\, Tr, \\ R^2 = {} & .90 \qquad D.W. = 2.24 \end{aligned}$$

$$A_t^c = \underset{(2.63)}{2{,}586.7662} + \underset{(1.53)}{.3836}\, A_{t-1}^c + \underset{(.35)}{1.8272}\, P_{t-1}^c + \underset{(3.42)}{8.4091}\, P^{*w}_t - \underset{(2.67)}{5.7680}\, FP_{t-1} - \underset{(2.42)}{2.0807}\, CPI_{t-1} + \underset{(2.46)}{152.6350}\, Tr,$$

$$R^2 = .98 \qquad D.W. = 1.79$$

$$A_t^r = \underset{(2.40)}{819.5296} + \underset{(1.99)}{.4572}\, A_{t-1}^r + \underset{(1.87)}{7.2875}\, P_{t-1}^r + \underset{(1.53)}{3.4364}\, P^{*w}_t - \underset{(1.99)}{8.8027}\, P_{t-1}^c - \underset{(.63)}{1.2358}\, FP_{t-1} - \underset{(2.26)}{2.0072}\, CPI_{t-1} + \underset{(2.20)}{82.7866}\, Tr,$$

$$R^2 = .96 \qquad D.W. = 1.81$$

$$A_t^s = \underset{(1.96)}{-123.9210} + \underset{(.48)}{.1386}\, A_{t-1}^s + \underset{(.37)}{.1710}\, P_{t-1}^s - \underset{(7.48)}{6.8075}\, P^{*w}_t + \underset{(4.72)}{18.2543}\, P_{t-1}^c + \underset{(6.68)}{1.3354}\, CPI_{t-1} + \underset{(3.85)}{28.8212}\, Tr.$$

$$R^2 = .98 \qquad D.W. = 1.74$$

In general, the signs of the coefficients are as expected. The response of corn hectarage to its own price is not significant, and rice area responds negatively to increases in corn prices, both findings made by previous studies also (USDA, June 1975). Corn and rice price elasticities of supply response, although on the low side for corn, are similar in magnitude to those calculated from other studies (see Ramalho de Castro and Schuh).

In the wheat and corn equations, the coefficient for P^{*w}_t is positively significant at the 5% level but is significant at only the 20% level in the riçe equation; removal of the wheat support price from the rice equation made little difference in the estimation results or in the reduced form discussed below. Corn area responds positively to an increase in the wheat support price because of interaction in the feed grain market, whereby as the price of wheat increases, the diversion of the crop to livestock feed is reduced, raising the demand for feed grains, such as corn. Further model development should include a livestock sub-sector to include more thoroughly these interactions.

Soybean area responds negatively and significantly at the 5% level to increases in the wheat support price. Engler and Singh, in an analysis of the impact of changes in the domestic support price of wheat on production and use of resources, found that because of the wheat-soybean double-cropping pattern in the wheat region of Rio Grande do Sul, the major wheat producing state, a wheat support price increase would reduce the relative profitability of soybeans and result in a shift of land use to wheat. In other areas of the country, as in the state of São Paulo, soybeans are grown as a single crop and may substitute more directly with wheat. In making hectarage decisions, soybean producers may respond more readily to the wheat support price than to own price, such that we find an insignificant response of soybean area to its own price in the estimated equation.

The results of the demand equations, estimated by TSLS are shown below, with standard errors in parentheses. (Because the properties of TSLS estimators are asymptotic only, such indications of statistical significance as standard errors are not really meaningful and are given here only because the preliminary OLS estimates of the demand equations were similar to the TSLS estimates.)

$$PCQD_t^w = \underset{(.84)}{38.4282} + \underset{(.02)}{.0261}\, PCInc_t - \underset{(.02)}{.0312}\, \bar{P}^w_t + \underset{(.01)}{.0177}\, P_t^r + \underset{(.01)}{.0036}\, CPI_t,$$

$$D.W. = 1.73$$

$$PCQD_t^c = \underset{(2.78)}{118.2781} + \underset{(.08)}{.0028}\, PCInc_t - \underset{(.09)}{.0900}\, P_t^c + \underset{(.06)}{.0272}\, \bar{P}_t^w + \underset{(.03)}{.0208}\, CPI_t,$$

$$D.W. = 1.62$$

$$PCQD_t^r = \underset{(2.96)}{62.6747} + \underset{(.08)}{.0385}\, PCInc_t - \underset{(.05)}{.0899}\, P_t^r + \underset{(.01)}{.1742}\, \bar{P}_t^w - \underset{(.01)}{.0460}\, CPI_t,$$

$$D.W. = 1.79$$

$$
\begin{aligned}
PCQD_t^s = \underset{(.34)}{.8766} &+ \underset{(.01)}{.0350}\, PCInc_t \\
&+ \underset{(.003)}{.00759}\, P_t^s + \underset{(.007)}{.0463}\, P_t^c \\
&- \underset{(.001)}{.0044}\, CPI_t. \\
D.W. &= 2.07
\end{aligned}
$$

In general, the signs of the coefficients are as expected a priori for all grains except soybeans; this result was obtained with several different formulations of soybean demand response.

The commercial wheat imports (not including P.L. 480) equation M_t^w, estimated by TSLS is, with standard errors in parentheses,

$$
\begin{aligned}
M_t^w = \underset{(177.62)}{2075.4929} &- \underset{(.13)}{.8390}\, QS_t^w \\
&- \underset{(.14)}{.8935}\, P.L.\ 480_t^w + \underset{(.06)}{.1008}\, FXR_t \\
&+ \underset{(1.19)}{2.1811}\, \bar{P}_t^w - \underset{(.74)}{.4558}\, CPI_t \\
&+ \underset{(16.02)}{30.8590}\, Tr. \\
D.W. &= 2.00
\end{aligned}
$$

As expected, as the domestic quantity supplied, QS_t^w, increases, commercial imports decrease. As foreign exchange reserves, FXR_t, increase, commercial imports increase. When the price at which the government sells the wheat to the mills, $\bar{P}_t^w$, increases, commercial imports increase. This would be due to the government's price intervention and its control over the entire wheat importing and domestic resale operations, such that $\bar{P}_t^w$ is not determined solely by market forces but is determined by the government in its revenue-making operations. As $\bar{P}_t^w$ is raised, more wheat may be imported to increase import revenues, perhaps at the expense of domestic production if domestic demand has not shifted outward, or imports may be increased to bring $\bar{P}^w$ down to a level more in keeping with consumer interests, and revenues sacrificed. What is important to note is that the influence of $\bar{P}^w$ on commercial imports is not the result of free market determination, but is the result of the government's separation of producer and consumer prices.

As P.L. 480 wheat imports increase, commercial imports decline, indicating that P.L. 480 imports do substitute for commercial imports. Abbot has also found this substitution effect for countries other than Brazil and Stam has discussed P.L. 480's detrimental effect on Canadian wheat exports. (With perfect substitution, a coefficient of −1 would have been obtained. Alternatively, had the P.L. 480 imports been distributed in such a way as to create additional demand, as was found by Rogers, Srivastava, Heady to have been the case in India, the coefficient on P.L. 480 might have been positive).

The results of the wheat support price equation for time period $t + 1$ estimated by OLS (t-ratios in parentheses) are

$$
\begin{aligned}
P^{*w}_{t+1} = \underset{(1.91)}{-23.6271} &\quad - \underset{(.89)}{.0434}\, M_t^w \\
&+ \underset{(2.27)}{.1361}\, P.L.\ 480_t^w + \underset{(.29)}{.2781}\, IP_t^w \\
&+ \underset{(7.07)}{.6367}\, CPI - \underset{(1.70)}{12.8860}\, Tr. \\
D.W. &= 1.63.
\end{aligned}
$$

As commercial and P.L. 480 wheat imports increase, so does the wheat support price. Depending upon the domestic supply and demand conditions (including the $\bar{P}_t^w$ at which the government sells the imported wheat), as imports increase, the revenues from wheat imports, and the support price formed in time t + 1 from these revenues, may increase. P.L. 480, in reducing the cost of total imports, contributes to increased revenues and increased support prices. Or, the increase in imports may prompt the government to raise the domestic support price in an attempt to reach self-sufficiency and decrease reliance on imports, particularly upon commercial imports which use scarce foreign exchange reserves, this also being a probable reason for the positive coefficient on international price.

Multiplier Analysis and Interpretation

The reduced form of the simultaneous equation system (1)–(7) was obtained, using linear approximation procedures described by Womack and Matthews. Only the relevant elements of the coefficients of the reduced form, π_1, and π_2, are shown in table 1, with the endogenous variables of the model on the far left-hand side of the table and a partial listing of the predetermined variables along the uppermost row of the table.[3]

[3] *PCInc* is shown in the reduced form of table 1 as an endogenous variable because it was linearized as a quotient of two other exogenous variables, total income and population.

Table 1. Brazil: Reduced Form

	Predetermined										
					Π_1					Π_2	
Endogenous	A_{t-1}^w	A_{t-1}^c	A_{t-1}^r	A_{t-1}^s	P_{t-1}^w	P_{t-1}^c	P_{t-1}^r	P_{t-1}^s	P^{*w}_t	$PL480_t^w$	
A_t^w	.79094								6.2814		1.
A_t^c		.3836				1.8272			8.4091		2.
A_t^r			.4572			−9.8027	7.2875		3.4634		3.
A_t^s				.1387		−18.2543		.1710	−6.8075		4.
$\bar{P}_t^w$										.01371	5.
P_t^c						.8008				.00415	6.
P_t^r							.6189			.02655	7.
P_t^s								.3646		−.02533	8.
P^{*w}_{t+1}									− .1236	.10096	9.
M_t^w										−.80906	10.
$PCQD_t^w$										.00243	11.
$PCQD_t^c$											12.
$PCQD_t^r$											13.
$PCQD_t^s$											14.
QD_t^w										.19093	15.
QD_t^c											16.
QD_t^r											17.
QD_t^s											18.
$PCInc_t$											19.
QS_t^w						2.4051			4.9644		20.
QS_t^c						2.4051					21.
QS_t^r							11.0850				22.
QS_t^s								.2172			23.

The initial impacts of a unit increase of 1,000 metric tons of P.L. 480 wheat during a single time period can be seen under the column variable, P.L. 480, in π_2. Of a total increase of 1,000 metric tons of P.L. 480 wheat, only about 19% or .00243 kilograms per capita, is reflected in a net increase in wheat consumption (fifteenth row). Such a small increase in net consumption occurs because 80% of the unit increase in P.L. 480 results in a displacement of commercial imports (tenth row).

The impacts on grain prices are not large. The price at which the government sells wheat to the mills, $\bar{P}_t^w$, increases by .0137 units, or 13 cruzeiros (fifth row), as would be expected from the intervention of the Brazilian government in the pricing system. The impact of P.L. 480 on $\bar{P}_t^w$ includes P.L. 480's direct effects on $\bar{P}_t^w$, $\bar{P}_t^w$ being increased as a result of the government's attempts either to increase import revenues or to keep them at a constant level when the price of commercial imports increases, and P.L. 480's indirect effects on $\bar{P}_t^w$, i.e., through P.L. 480's negative effects on commercial imports and the corresponding increase in consumer prices which may be implied.

The reduced form also shows, as a result of demand interactions among grains, increases in corn and rice prices—by .00415 units, or 4 cruzeiros and .02655, or about 26 cruzeiros, respectively, and a decrease in soybean price—by .02533 units or 25 cruzeiros. There is a very small impact (negligible enough to be ignored) on consumption of grains other than wheat. Even given small price impacts of P.L. 480, negligible consumption effects could result if substitutions among grains due to price changes canceled consumption impacts. It is also possible that consumption effects are not adequately represented, perhaps due to the linearization of the demand equations needed for the reduced form. However, the impact of P.L. 480 on the next period's wheat support price, P^{*w}_{t+1}, is positive—an increase of 1,000 metric tons of P.L. 480 wheat increases the wheat support price by .10096 units or 100 cruzeiros.

The delay multipliers (table 2) indicate the impact of P.L. 480 during successive time periods, and because of the use of lagged price in the area response equations, are used to evaluate the production effects of P.L. 480. There is an initially positive impact of P.L. 480 wheat imports on wheat, corn, and rice production in the first time period after the initial change (year one), with the effects declining over time and in an oscillatory fashion for wheat and corn. An increase of 1,000 metric tons of P.L. 480 wheat leads to an increase of 500 metric

Table 2. Brazil: Production Multipliers

Year	Wheat	Corn	Rice	Soybeans
		Delay Multipliers		
1	.50121	.00998	.29430	−.00550
2	−.06192	−.00799	.18214	−.00201
3	.00765	.00640	.11236	−.00073
4	−.00012	−.00410	.04318	−.00010
5	.00000	.00169	.00633	−.00009
6		−.00029	.00014	−.00000
7		.00001	.00000	
8		.00000		
		Cumulative Multipliers		
1	.50121	.00998	.29430	−.00550
2	.43929	.00199	.47645	−.00751
3	.44693	.00839	.58881	−.00824
4	.44682	.00428	.63198	−.00833
5	.44682	.00597	.63832	−.00834
6		.00569	.63846	−.00834
7		.00569	.63846	

tons of domestic wheat in the first year, its effects declining rapidly thereafter. Also shown is an increase of about 9 metric tons of corn in the first year, with zero effect in the eighth year and an increase of 294 metric tons of domestic rice production, which declines until reaching zero in the seventh period. The impact on soybean production is mildly negative in the first time period and in successive periods; there is an initial decline of about 5 metric tons of domestic production, the effect reaching zero in the fifth year.

The cumulative multipliers show the effect of a sustained unit increase of P.L. 480 wheat over time (table 2). The point at which the value of the cumulative multiplier reaches a stable value, defined to a particular decimal place, is the long-run multiplier and for wheat, corn, and rice are .447, .0056, and .638. That is, a sustained increase of 1,000 metric tons of P.L. 480 wheat would result in increased domestic production of 447 metric tons of wheat in five years, of about 5 metric tons of corn in seven years, and of 638 metric tons of rice in seven years; it would also result in a decrease of eight metric tons of soybeans in six years. The net effect of a sustained increase of 1,000 metric tons of P.L. 480 wheat imports then would be to increase domestic grain production by 108% (obtained by totalling the long-run multipliers of each grain and dividing by 1,000).

It is stressed that the model and reduced form results pertain to the grain sector of the entire country, although much of the wheat production is concentrated in Rio Grande do Sul, which accounted for some 67% of the area sown to wheat in 1970. In this region, production substitutions were primarily between wheat and pastureland for cattle. (See Knight and Singh and Ahn.) However, wheat production has been increasing in other areas of the country—as in the state of Sao Paulo, where wheat production, averaging only a little more than 4,000 metric tons during the 1960s, grew to 74,000 metric tons in 1974. Here, there was little competition between crops and cattle grazing for the use of land; area in pasture increased in the regions of the state where cropland increased and decreased in the regions where cropland decreased (USDA, June 1975, p. 24). It was felt, therefore, that a countrywide model, as opposed to a regional model, would better include this diversity and would be needed to obtain a better measure of the overall impact of P.L. 480 imports; this countrywide model should provide an interesting comparison to a regional model.

Conclusions

On the basis of the above results obtained from a model of Brazil's grain sector, which included demand and supply interrelationships among the grains and specific government intervention policies in the importing and the domestic marketing of wheat, it appears that Brazil has managed to use P.L. 480 wheat imports in a beneficial way for domestic production. Primarily because of the use of revenues from wheat imports to encourage production by supporting the price to domestic wheat producers, wheat production has tripled from 1952–71, and has increased from 30% to 53% of total consumption.

On the other hand, the results also show that P.L. 480 imports have displaced commercial wheat imports, in spite of the Usual Marketing Requirements imposed, and this disruption of international commercial wheat markets has obvious implications for third-country wheat exporters.

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References

Abbott, P. "Developing Countries and International Grain Trade." Ph.D. thesis, Massachusetts Institute of Technology, 1976.

Adams, D. W., Guillermo A. Guerra, Philip Warnken,

Richard G. Wheeler, and Lawrence W. Witt. *Public Law 480 and Colombia's Economic Development.* Lansing: Michigan State University, Mar. 1964.

Berlage, L. "Demand and Supply Policies for Foodgrains in Bangladesh." Ph.D. thesis, Massachusetts Institute of Technology, 1972.

Blandford, D., and J. A. von Plocki. "Evaluating the Disincentive Effect of P.L. 480 Food Aid: The Indian Case Reconsidered." Dep. Agr. Econ. Cornell Internat. Agr. Mimeo. 55, Cornell University, July 1977.

Brazil, Centro de Estudos Agricolas, Getulio Vargas Foundation. Personal Communication, 1977.

Brazil, Comissao de Financiamento da Producao (CFP), Ministerio da Agricultura, Departmento de Pesquisas Economica. Personal Communication, 1977.

Brazil, Fundacao Instituto Brasileiro de Geografia e Estatistica (FIBGE). *Anuario Estatistico do Brasil.* Rio de Janeiro, various issues.

Brazil, Instituto de Economia Agricola da Secretaria da Agricultura do Estado de São Paulo. Personal Communication, 1977.

Brazil, Ministerio da Agricultura. *Portarias,* 1954–1964.

Brazil, Subsecretaria de Planejamento e Orcamento (SUPLAN)—Fundacao Instituto Brasileiro de Geografia e Estatistica, Escritorio de Estatistica. Personal Communication, Brasilia, 1978.

Brazil, Superintendencia Nacional de Abastecimento. *Portarias,* 1965–75.

Day, R. H., and I. J. Singh. *Economic Development as an Adaptive Process: The Green Revolution in the Indian Punjab.* London: Cambridge University Press, 1977.

Dudley, L., and R. Sandilands. "The Side Effects of Foreign Aid: The Case of Public Law 480 Wheat in Colombia." *Econ. Develop. and Cultur. Change.* 23(1975):325–36.

Engler, J., and J. J. Singh. "Production Response to Technological and Price Changes: A Study of Wheat and Cattle Farming in Southern Brazil." Dep. Agr. Econ. and Rural Soc. Occ. Pap. No. 33, Ohio State University, 1971.

Foote, R. J. *Analytical Tools for Studying Demand and Price Structures.* Washington, D.C.: USDA Handbook No. 146, Aug. 1958.

Hatti, N. "The Impact of Assistance under P.L. 480 on the Indian Economy 1956–1970." *Econ. and Hist.* 20(1972):23–40.

International Monetary Fund (IMF). *International Financial Statistics.* Washington, D.C., various issues.

International Wheat Council. *Review of the World Wheat Situation.* London, various issues.

Isenman, P., and H. W. Singer. "Food Aid: Disincentive Effects and Their Policy Implications." *Econ. Develop. and Cultur. Change* 25(1977):205–37.

Knight, P. T. *Brazilian Agricultural Technology and Trade, A Study of Five Commodities.* New York: Praeger Publishers, 1971.

Labys, W. C. *Dynamic Commodity Models: Specification, Estimation and Simulation.* Lexington, Mass.: D.C. Heath & Co., 1973.

Leamer, E. E., and R. M. Stern. *Quantitative International Economics.* Chicago: Aldine Publishing Co., 1970.

Mann, J. S. "The Impact of Public Law 480 Imports on Prices and Domestic Supply of Cereals in India." *J. Farm Econ.* 49(1967):131–45.

Paiva, R. M., S. Schattan, and C. F. Trench de Freitas. *Brazil's Agricultural Sector: Economic Behavior, Problems and Possibilities.* Fifteenth Internat. Conf. of Agr. Econ., São Paulo, Brazil, 19–30 August 1973.

Ramalho de Castro, J. P., and G. E. Schuh. "An Empirical Test of an Economic Model for Establishing Research Priorities: A Brazil Case Study." *Resource Allocation and Productivity in National and International Agricultural Research,* ed. T. M. Arndt, D. G. Dalrymple, and V. M. Ruttan, Minneapolis: University of Minnesota Press, 1977.

Rogers, K. D., U. K. Srivastava, and E. O. Heady. "Modified Price, Production and Income Impacts of Food Aid under Market Differentiated Distribution." *Amer. J. Agr. Econ.* 54(1972):201–08.

Seevers, G. "An Evaluation of the Disincentive Effect Caused by P.L. 480 Shipments." *Amer. J. Agr. Econ.* 50(1968):630–42.

Sen, S. R. "Impact and Implications of Foreign Surplus Disposal on Underdeveloped Economies—The Indian Perspective." *J. Farm Econ.* 42(1960):1013–51.

Singh, I., and C. Y. Ahn. "A Dynamic Multi-Commodity Model of the Agricultural Sector, A Regional Application in Brazil." *Europ. Econ. Rev.* 11(1978):155–79.

Stam, J. M. "The Effects of Public Law 480 on Canadian Wheat Exports." *J. Farm Econ.* 46(1964):805–19.

United Nations, Food and Agricultural Organization. *Production Yearbook.* Rome, various issues.

———. *Trade Yearbooks.* Rome, various issues.

U.S. Department of Agriculture (USDA). *Agricultural Development in Brazil.* Washington, D.C.: ERS For. Agr. Econ. Rep. No. 109, June 1975.

———. *P.L. 480 Concessional Sales.* Washington, D.C.: ERS, For. Agr. Econ. Rep. No. 142, Dec. 1977.

U.S. Department of Agriculture (USDA). *Reference Tables on Rice Supply—Distribution for Individual Countries.* Washington, D.C.: For. Agr. Serv. FR1-76, May 1976a.

———. *Reference Tables on Wheat, Corn and Total Coarse Grains Supply—Distribution for Individual Countries.* Washington, D.C.: FG 9-76, May 1976b.

———. *Title I, Public Law 480: Total Amounts Shipped by Country and Commodity,* various issues.

Womack, A. W., and J. L. Matthews. "Linear Approximations of Nonlinear Relationships by the Taylor's Series Expansion Revisited." *Agr. Econ. Res.* 24(1972):83–101.

Wheat Acreage Supply Response under Changing Farm Programs

B. J. Morzuch, R. D. Weaver, and P. G. Helmberger

Planted wheat acreage supply elasticities are estimated for each of several leading wheat-producing states. Estimates of elasticities for the aggregate of these states are 0.77, 0.45, and 0.52 for spring wheat, winter wheat, and all wheat, respectively, but there is considerable heterogeneity among states. Acreage allotments and marketing quotas appear to have destroyed the role of prices in allocating acreage between wheat and other crops during the years 1950 and 1954–64. Estimates were obtained using multiple regression analysis of time-series data for the period 1948–74. This period was subdivided in order to take account of changing farm programs.

Key words: farm programs, regression analysis, supply elasticities, wheat acreage.

In their survey of agricultural price analysis, Tomek and Robinson call attention to the difficulties encountered in supply analysis and to the inadequacy of the elasticity estimates currently available. Supply estimation is particularly difficult for major commodities subject to farm programs. These programs change every three to five years and tend to complicate supply estimation because relevant variables and structural parameters may change over time. While supply equations must be conceptualized under alternative policy regimes, conserving degrees of freedom often necessitates approximations that are difficult to justify on strictly a priori grounds.

The need for good estimates of supply elasticities is great, however, and researchers continue to experiment with alternative approaches. Developing outlook information, predicting the consequences of proposed changes in farm policy, analyzing the welfare implications of commodity storage, and quantification of spatial equilibrium models are examples of research areas that require estimates of supply elasticities.

The purpose of this paper is to present the main results of an analysis of wheat acreage supply response. Unlike other studies of wheat supply, this study uses futures prices as a proxy for expected prices for wheat and competing crops. A different acreage response equation is conceptualized for each of three periods since World War II in light of changing farm programs for wheat. Supply equations are estimated for each of several major wheat states rather than for the nation as a whole. A considerable effort was made to measure all variables with as much precision as possible.

Our estimates of structural parameters support the following conclusions. First, during the years when acreage allotments and marketing quotas were not in effect, the response of wheat acreage to the price of wheat relative to prices of competing crops was larger than previous supply estimates would suggest. Second, there is a considerable heterogeneity in supply response among major wheat-producing states. Third, farm policy during the "quota years" appears likely to have destroyed the role of price in allocating acreage between wheat and competing crops. Finally, the voluntary nature and substitution and other provisions of programs beginning in the mid-sixties restored an allocative role to wheat price not unlike that under "free market" conditions. It appears that policy changes introduced in the sixties were quite successful in

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making greater use of the market mechanism in resource allocation.

Our analysis draws upon previous work in several important respects, but, at the same time, questions some existing research procedures and results. Gardner has proposed using futures prices as proxies for expected prices; our findings lend further support for this thesis. To take account of farm programs Lidman and Bawden inserted several program variables in a regression equation, giving little attention to the modeling of producer decision making in the face of changing programs over time. Garst and Miller improved upon the Lidman and Bawden work, in effect allowing new variables to appear (disappear) and parameters to change as programs varied. Their decision to include land diversion and set-asides as independent variables is of some concern, however, in that decisions to plant and divert are made simultaneously. Some of their independent variables may be endogenous, thus raising the question of simultaneous equations bias. We return to this issue later. Garst and Miller and Houck et al. insert price as an independent variable, but price is not expressed relative to the prices of competing crops. Their procedure receives little support from economic theory. Unlike the previous works of Garst and Miller, Lidman and Bawden, and Houck et al., we do not assume that wheat acreage supply elasticities are the same for quota and nonquota years. As a final preliminary, the decision to disaggregate supply analysis to the state level stands in contrast to previous work and allows greater accuracy in the definition of variables. For instance, Lidman and Bawden divided lagged U.S. wheat price by a lagged U.S. index of feed grain and hay prices received by farmers. This index is dominated by U.S. corn prices which, while quite appropriate for wheat producers in the Corn Belt, would seem to be much less so for wheat producers in the plains states.

Conceptualizing Acreage Response Functions under Alternative Policies

In major wheat-producing areas, farmers have flexible production capacity that can be used to produce various crops other than wheat, including feed grains, rye, soybeans, flax, etc. We assume that producers allocate acreage among competing crops to maximize expected profit.[1] Under free market conditions, acreage planted to wheat may be viewed as a function of expected crop prices, exogenous input prices, variables measuring climatic expectations and endowments, the nature and extent of fixed-scale factors, and the current state of technology. Such a relationship is merely one among several reduced-form relationships, others being those for output, inputs other than acreage, and endogenous input prices (Weaver 1978). In addition, theory of the firm suggests that the function in question is homogenous of degree zero in prices; and increase in all prices will have no impact on planting decisions. This suggests that farmers are concerned with relative expected crop prices in allocating acreage among competing crops and would not respond to a proportional change in all expected prices. Although this point would seem clear even on an intuitive basis, typical acreage response functions estimated in the past have not been restricted to be linearly homogenous in prices.

A simple wheat acreage response function may be hypothesized under these conditions as follows:

$$(1)\quad WAP = \alpha_0 + \alpha_1\, ERP + \alpha_2\, TREND + \epsilon,$$

where WAP represents acreage planted to wheat; ERP represents the expected relative price, i.e., the expected price of wheat divided by an index of expected prices for competing crops; $TREND$ is self-explanatory; and ϵ is a stochastic term. $TREND$ is inserted to capture the effects of omitted variables that may have exerted systematic effects over time. For example, if technological change has tended to increase wheat yields less rapidly than the yields for competing crops, then for a given ERP, acreage planted to wheat would likely decline. In this study, equation (1) is hypothesized for each of the several major wheat-producing states with the variables defined accordingly. Because equation (1) makes no provision for farm programs, it is hypothesized for those years during which no programs were in effect. These "free market" years consisted of 1948, '49, '51, '52, '53, and 1974. We argue, however, that with suitable modifications, equation (1) may also be appropriate for the years 1965–73.

[1] Similar results undoubtedly would follow from a model of risk-averse choice. However, where risk measures are independent of expectations, exclusions of these variables will not bias our results.

The wheat programs for 1965–70 were voluntary (see Cochrane and Ryan). Wheat producers were awarded direct payments if they abided by their allotments and idled specified minimum percentages of their acreage allotments. Land diversion was not used in 1967 and 1968, but for the other years (1965, '66, '69, and 1970) land beyond the minimum diversions could be idled for additional payments. Wheat producers also were required to maintain normal acreages in conservation uses. Price supports through the nonrecourse loan system still were available to participants, but at greatly reduced levels relative to earlier years. The strategy of the new programs was aimed at allowing wheat output to be marketed through normal commercial channels. Of considerable relevance to the present study were the so-called substitution provisions included in both the wheat and feed grain programs. The feed grain program was similar in essential respects to that for wheat. Farmers who participated in both the wheat and feed grain programs could substitute acreage of feed grains for wheat, or wheat acreage for feed grains, within the total acreage permitted under both programs. A similar provision was open to the producer who had an oat-rye acreage base and was willing to divert some of that base to conservation uses. Wheat could be planted on the oat-rye base acreage. Finally, an overplanting provision allowed the producer to overplant up to 50% of the farm's permitted wheat acreage. The excess production had to be stored under bond, but could be marketed in future years under certain specified conditions. The substitution and storage provisions together with the voluntary nature of the program allowed considerable room for farmers to allocate acreage among competing crops on the basis of expected prices.

Relative to the 1965–70 programs those for 1971, '72, and '73 constituted an even smaller encumbrance on the allocative role of crop prices. Under the wheat and feed grain setaside programs for the latter three years, acreage diversion (set-aside) was required under most options in return for eligibility for direct payments. All remaining land, with the exception of a conserving base, could be allocated among crops in any way the farmer chose. The option of voluntary diversion of cropland beyond minimum diversions for additional payments was also available to feed grain producers in 1972 and to wheat producers in 1972 and 1973.

The above discussion indicates that wheat producers had considerable leeway in allocating land among competing crops over the period 1965–73. Farm programs served mainly to provide farmers with another cropland alternative, viz., the diversion of land for direct payments and other benefits. A wheat acreage response function may be hypothesized under these conditions as follows:

$$(2) \quad WAP = \gamma_0 + \gamma_1\, ERP + \gamma_2\, TREND + \gamma_3\, RUDC + \gamma_4\, MAXD + e,$$

where *ERP* and *TREND* are as explained above, *RUDC* equals an estimated diversion payment per bushel divided by the index of expected prices for all other crops, and *MAXD* equals the upper limit on the extent of permissible land diversion. The homogeneity condition for returns to land diverted is maintained as in the case for returns to land planted to wheat. It is hypothesized that γ_3 is negative in that the higher the relative diversion payment rate, the more land would be diverted and the less land would be planted to wheat. It is hypothesized that γ_4 is negative in that to the extent *MAXD* was actually binding, raising its value would have the effect of increasing land diversion (Weaver 1978a).

In order to conserve degrees of freedom we assume that $\alpha_0 = \gamma_0$, $\alpha_1 = \gamma_1$, and $\alpha_2 = \gamma_2$. This allows using data for the "free market" years along with data for the years 1965–73 for estimating the parameters of equation (2). The two variables *RUDC* and *MAXD* are set equal to zero for the "free market" years, a procedure that disallows acreage diversion during those years. Importantly, we are assuming that the acreage supply equation has the same slope for "free market" years as it did during the "land diversion" years. We also assume that the coefficients for *RUDC* and *MAXD* are the same for 1965–70 as for 1971–73. These are restrictive hypotheses which, given a sufficiently large sample, could be subjected to empirical testing. It should be stressed, however, that our hypothesis regarding slopes is much less restrictive than that maintained by previous supply analysts who have assumed constant supply slopes between quota and nonquota years. To this matter we now turn.

Beginning in 1954 and continuing through 1963, the wheat program involved price supports, acreage allotments, and marketing quotas. Producers who did not exceed their wheat acreage allotments could place their production under nonrecourse loans which in-

cluded price support. They were, therefore, guaranteed a minimum price for wheat. Farmers who exceeded allotments and failed to store their excess production were subject to a penalty tax on the excess marketed. For each acre planted (harvested, after 1955) in excess of the allotment, the producer was required by law to pay a tax equal to the product of his weighted average yield over the previous three years and a per bushel tax. In addition, for some years the future allotment was reduced for the farmer who did not comply with his current allotment. After 1957, noncommercial wheat farmers could harvest thirty acres without penalty so long as the output was fed on the farm. Farmers who planted not more than fifteen acres of wheat were exempt from marketing quota penalties, a provision that was attractive to many farmers in the Corn Belt who were not mainly wheat producers.

Given a package of specific program parameters (allotments, penalties, and price supports) various responses by producers could be rationalized. Agricultural Stabilization and Conservation Service data show that in major wheat-producing states there was widespread compliance with allotments. If penalties were sufficiently onerous and all allotments were actually binding, then acreage allotment alone would determine planted (or harvested) wheat acreage, subject to the exception of land diversion programs to be discussed in a moment, and there would be no basis for including *ERP* as a relevant variable. In other words, the conventional concept of an upward-sloping supply simply would not apply. Hadwiger (p. 197) argues, however, that "during the Benson administration, program rules came to be structured somewhat more in favor of the noncompliers or violators, to the point where the advantage for many producers seemed definitely to be in noncompliance with the program." He further notes that in 1960, the last year of the Benson reign, "43.1 million acres of wheat were in compliance on a total allotment of 50.6 million acres" (p. 194). The 15-acre exemption, the "wheat-for-feed" exemption, and other provisions indicate that the relative price of wheat might be a relevant variable in determining wheat acreage. On balance we are inclined to include *ERP* as an independent variable, but with the expectation that its coefficient is likely to be a good deal less than for the nonquota years and might in fact equal zero.

The wheat program for 1950 involved acreage allotments. Farmers who exceeded allotments paid no penalties but lost price supports. Penalties also were dropped in 1964, although allotments and loss of allotment history were maintained. Importantly, there were no substitution provisions in either 1950 or 1964. For this reason, these two years were included in the "quota years."

In addition to direct acreage controls, land diversion opportunities were offered to producers during many of the quota years. These programs required that the allotment be reduced by the number of acres diverted. Land diversion introduced an alternative use of the allotted wheat acreage, which was constrained by a maximum allowable diversion (*MAXD*) and encouraged by a per bushel incentive equal to a percentage (*PERRU*) times the loan rate.

The acreage supply response hypothesized for the quota years is

$$(3)\quad WAP = \beta_0 + \beta_1\, ERP + \beta_2\, WAL + \beta_3\, PERRU + \beta_4\, MAXD + \mu,$$

where *WAL* equals the wheat acreage allotment, μ is a stochastic term, and remaining variables are as defined previously. Dividing the per bushel payment for land diversion by the loan rate is equivalent to using *PERRU* and again invokes the homogeneity condition in that only those producers who complied with allotments were eligible to participate in land diversion programs. Because the sample period spans only fifteen years and the number of observations is limited, trend was excluded from (3). It is hypothesized that β_1 and β_2 are positive and β_3 and β_4 are negative.

Data

Acreages. The spring wheat states in this study are North Dakota, South Dakota, and Montana. For any one year during the sample period, these three states accounted for a minimum of 76% of U.S. spring wheat production. The winter wheat states are Colorado, Illinois, Indiana, Kansas, Montana, Nebraska, Ohio, Oklahoma, Texas, and Washington. For any one year, these ten states accounted for a minimum of 78% of U.S. winter wheat production. For the spring wheat equations, acreage consists of acres planted to both durum wheat and other spring wheat. The acreage data are taken from various issues of *Crop Production-Revised Estimates* and of *Field Crops-Revised Estimates by States,* both

series published by the U.S. Department of Agriculture (USDA).[2]

Prices. The expected prices for durum wheat and for other spring wheat are measured by the closing futures prices for the two kinds of wheat at Minneapolis on 15 April for the contract delivery month of September. The expected prices for certain other commodities were measured in an analogous fashion. Closing futures prices and contract delivery months were matched with planting dates and harvest dates, respectively, using data from *Usual Planting and Harvesting Dates,* USDA. For all winter wheat states, the closing futures prices on 30 September for delivery in July were used. Chicago quotations were used for soft winter wheat, oats, soybeans, and corn for grain. Kansas City and Minneapolis quotations were used for hard winter wheat and rye, respectively. Winnipeg quotations were used for barley and flax. The futures prices were taken from various issues of the *Wall Street Journal* for the period 1948–74.

Futures prices are unavailable for a number of crops grown in the twelve states. These include hay, sugarbeets, corn for silage and forage, sorghum for grain, forage and silage, potatoes, edible beans, edible peas, mung beans, rice, peanuts, popcorn, cotton, clover, broomcorn, buckwheat, and cowpeas. One-period lagged prices for these crops were chosen as a proxy for the unobtainable futures prices in the construction of an appropriate other crops price index corresponding to either winter wheat or spring wheat. Price information for most crops was taken from various issues of the USDA's *Agricultural Statistics* and *Crop Values*. Prices for crops such as hay, corn for silage and forage, and sorghum for silage and forage were estimated with the assistance of the Statistical Reporting Service, USDA.

A spring wheat price index, its corresponding other crop price index, a winter wheat price index, and its corresponding other crop price index, were derived using Divisia weights. This approach differs from the Paashe or Lespeyres approach in that the weights used by the latter two consist of a given base period weight, whereas the Divisia approach uses weights that change from year to year. The attractiveness of the Divisia scheme lies in its use of changing weights that in turn reflect the changing importance of commodities in terms of both their prices and quantities produced (Tornquist). The quantities used in the formation of these indices were the production figures associated with each crop. The sources of data on production are the same as for wheat acreages.

Government programs. The sum of the domestic marketing certificate and export marketing certificate values for wheat was used as the estimated diversion payment per bushel for 1965. The domestic marketing certificate value and the marketing certificate payment rate were used, respectively, for the periods 1966–70 and 1971–73. These data are taken from *Wheat-1978 Program*, USDA. Data on wheat acreage allotments, diverted acres, percentages of allotments used in figuring maxima for diverted acreages, and the percentages of loan rates used in figuring diversion payments during the quota years are taken from various issues of *Wheat Situation,* published by the USDA, and from Cochrane and Ryan.

Empirical Results

Where contemporaneous correlation exists among the error terms in a set of equations, generalized least squares (GLS) estimation of all equations taken together yields more efficient estimates than does ordinary least squares (OLS) estimation of each equation separately (Kmenta, pp. 517–29). Because of number of observations available and the number of parameters to be estimated there were insufficient degrees of freedom for GLS to be used.

Equations (2) and (3) were estimated by OLS for spring wheat in three states and winter wheat in ten states for the period 1948–74. Estimates for equation (2) are given in table 1. These estimates indicate that acreage planted to wheat was quite responsive to the relative price of wheat in nonquota years. The estimated coefficients for *ERP* are positive in all cases. The t-ratios range from 0.42 to 6.62 and exceed 1.8, the critical value at the 5% level of significance using a one-tailed test, in eight of the thirteen cases. Where the Durbin-Watson (D-W) statistics are low (e.g., Montana and Colorado), t-ratios are probably high.

Price elasticities vary considerably across states. Elasticities range from 0.61 to 0.95 for

[2] Interested readers may write to the senior author for data used in the analysis.

Table 1. Wheat Acreage Response Functions, Major Wheat Producing States, 1948–49, 1951–53, and 1965–74

State	Regression Coefficients (with t-Ratios)[a]					R^2	$D-W$	Own-Price Elasticity
	CONST	*ERP*	*TREND*	*RUDC*	*MAXD*			
North Dakota	3.250	5.900	−.326	−.018	−.082	.87	2.09	.71
	(1.76)	(3.98)	(−1.94)	(−.72)	(−.21)			
South Dakota	1.273	2.127	−.125	−.073	−.046	.98	1.55	.99
	(3.14)	(6.62)	(−1.25)	(−13.75)	(−.49)			
Montana[b]	3.577	.673	−.244	−.085	−.102	.80	.54	.27
	(1.67)	(.42)	(−.78)	(−3.06)	(−.35)			
Colorado	2.863	.581	−.032	−.031	−.071	.74	1.02	.22
	(4.70)	(1.22)	(−.13)	(−3.04)	(−.33)			
Illinois	.721	.938	.053	−.003	−.138	.52	1.69	.61
	(.76)	(1.20)	(.16)	(−.23)	(−.66)			
Indiana	.285	1.107	−.033	−.007	−.152	.75	1.76	.93
	(.40)	(1.88)	(−.10)	(−.80)	(−.93)			
Kansas	9.360	4.522	−.242	−.116	.161	.81	1.76	.41
	(4.60)	(2.71)	(−1.04)	(−3.24)	(.21)			
Montana[c]	1.200	.259	−.007	−.057	−.387	.71	1.16	.13
	(1.12)	(.32)	(−.04)	(4.24)	(−1.81)			
Nebraska	3.191	1.207	−.168	−.060	.002	.90	2.00	.37
	(4.54)	(2.00)	(−.86)	(−5.98)	(.01)			
Ohio	.573	1.408	−.111	−.025	−.116	.82	1.93	.95
	(.63)	(1.92)	(−.30)	(−2.21)	(−.54)			
Oklahoma	3.112	2.380	−.284	.018	.140	.69	2.56	.46
	(3.23)	(3.52)	(−1.12)	(.93)	(.33)			
Texas	3.414	2.105	−.268	−.028	−.192	.58	1.61	.46
	(2.64)	(1.87)	(−.56)	(−.97)	(−.29)			
Washington	1.421	.637	−.273	.025	.054	.47	1.35	.29
	(2.81)	(1.75)	(−1.03)	(2.81)	(.31)			

[a] The dependent variable is acreage planted to spring wheat (North and South Dakota, Montana) or to winter wheat (remaining states including Montana); *CONST* is the constant term; *ERP* is the ratio of the expected price of wheat to the index of expected prices for other crops; *TREND* has gaps for missing years; *RUDC* is the ratio of the diversion payment per bushel to the index of expected prices for crops other than wheat; and *MAXD* is maximum allowable acreage diversion. See text for details.
[b] Spring wheat.
[c] Winter wheat.

the three Corn Belt states and from 0.22 to 0.46 for the remaining winter wheat states. This is not too surprising in that one might expect an inverse relationship between extent of specialization and elasticity of acreage response. Acreage elasticities were relatively high for North and South Dakota. It may be noted that the spring wheat states tend to be less specialized than major winter wheat states.

Aggregate supply elasticities were estimated as weighted averages using mean acreages for individual states as weights. Montana was excluded. (In much of our statistical work, the estimates for Montana were neither consistent with expectations nor with the results for other states.) The aggregate acreage supply elasticities for spring wheat, winter wheat, and all wheat combined are 0.77, 0.45, and 0.52, respectively. Previous acreage supply elasticities by Garst and Miller (p. 34) for spring, winter, and all wheat are 0.04, 0.19, and 0.17, respectively. The elasticity reported by Houck et al. (p. 37) equalled 0.39. Over the period 1954–70, Lidman and Bawden (p. 331) found that lagged wheat price was not significant in explaining acres planted to wheat. In most of their formulations the estimated coefficient for price was, in fact, negative.

Although the estimated coefficients for *RUDC* and *MAXD* tend to be negative, as expected, the t-ratios are low. Yet we know that substantial acreages were diverted under major programs during the period 1965–73, and it would seem strange indeed if these idled acres did not reduce at least to some extent acreage planted to wheat. The low t-ratios may be the result of the high levels of correlation observed between *RUDC* and *MAXD*. Moreover, it may well be that the land diversion programs in question were too complex to be represented adequately by the inclusion of

Table 2. Wheat Acreage Response Functions, Major Wheat Producing States, 1948–49, 1951–53, and 1965–74

State	Regression Coefficients (with *t*-Ratios)[a]				R^2	$D-W$	Own-Price Elasticity
	CONST	*ERP*	*TREND*	*DIV*			
North Dakota	2.549	6.375	−.017	−.225	.82	1.63	.77
	(1.37)	(4.02)	(−.31)	(−1.36)			
South Dakota	.284	2.954	−.131	−.106	.95	.82	1.40
	(.25)	(3.17)	(−6.18)	(−.59)			
Montana[b]	−.581	3.740	−.109	.128	.64	.71	1.50
	(−.25)	(2.09)	(−1.66)	(.32)			
Colorado	2.770	.690	−.060	−.175	.77	1.08	.26
	(6.25)	(1.93)	(−3.21)	(−1.14)			
Illinois	1.098	.636	−.001	−.140	.59	1.81	.41
	(1.47)	(1.03)	(−.09)	(−1.55)			
Indiana	1.158	.406	−.010	−.332	.88	1.88	.34
	(2.50)	(1.07)	(−1.06)	(−4.30)			
Kansas	10.721	3.528	−.231	−.265	.81	2.16	.32
	(6.95)	(2.75)	(−3.29)	(−1.63)			
Montana[c]	1.219	.244	.107	−.277	.49	.81	.13
	(1.35)	(.35)	(3.12)	(−1.50)			
Nebraska	3.639	.884	−.109	−.166	.91	2.61	.27
	(6.51)	(1.84)	(−5.96)	(−2.66)			
Ohio	1.770	.466	−.043	−.584	.90	2.28	.31
	(2.59)	(.85)	(−3.12)	(−3.71)			
Oklahoma	3.885	1.827	.024	−.172	.65	2.31	.36
	(4.72)	(3.04)	(.61)	(−.75)			
Texas	3.847	1.818	−.078	−.151	.54	1.59	.40
	(3.63)	(2.02)	(−1.57)	(1.11)			
Washington	1.901	.296	.035	−.089	.30	1.22	.14
	(4.81)	(1.01)	(1.94)	(−.27)			

[a] All variables are defined as in table 1 except *DIV* equals acreage diverted under both the wheat and feed grain programs. See text for details.
[b] Spring wheat.
[c] Winter wheat.

but two variables. For example, the two program variables do not take account of minimum diversion, payment rates for additional diversion, allotments, and several other program details that were likely of some importance in determining planted wheat acreage. While further work on this problem may be useful, the number of observations is limited in light of the number of parameters that might require estimation in models more complicated than those considered here.

As part of our exploration, equation (1) was modified by the inclusion of diverted acres (*DIV*) as an independent variable. The variable *DIV* equals the land diverted under both the feed grain and wheat programs and was zero for the free market years and nonzero for the years 1965–73. As noted previously, including *DIV* as an independent variable risks simultaneous equations bias in that diverted and planted acreages are probably endogenous in any reasonable model of producer decision making.

Alternatively, the estimates of equation (1) modified by including *DIV* may be unbiased if it is assumed that the expected value of the dependent variable is conditional on all independent variables including *DIV*.[3] On this interpretation, applicable to the estimates discussed below much as it is to the previous results of Garst and Miller, the estimated equation can be used only in prediction if knowledge of an estimate of the extent of land diversion is available prior to planting times. Clearly this approach, aside from problems of application, is less powerful than one which involves estimation of the reduced forms of a structural model.

Estimates of equation (1) modified by the inclusion of *DIV* are given in table 2. Again, the results for *ERP* are impressive judged by the usual economic statistical criteria. The associated aggregate acreage supply elasticities, again excluding Montana, are 0.90, 0.32, and 0.46 for spring wheat, winter wheat, and all

[3] For a presentation of the relevant theorems and a brief critique, see Malinvaud (pp. 614–17).

Table 3. Wheat Acreage Response Functions, Major Wheat Producing States, 1950 and 1954–64

State	Regression Coefficients (with t-Ratios)[a]					R^2	D–W
	CONST	*ERP*	*WAL*	*PERRU*	*MAXD*		
North Dakota	−.211	−.188	1.009	−.797	.115	.85	1.40
	(−.12)	(−.17)	(4.70)	(−.42)	(.36)		
South Dakota	−1.963	.210	1.337	.076	−.100	.78	2.51
	(−1.37)	(.22)	(3.58)	(.06)	(−.17)		
Montana[b]	−2.555	−1.310	1.616	1.297	−.115	.45	1.61
	(−.77)	(−.46)	(2.00)	(.45)	(−.13)		
Colorado	−1.933	−2.620	3.098	4.379	−2.165	.73	1.12
	(−1.17)	(−3.50)	(3.75)	(2.71)	(−2.97)		
Illinois	1.550	−.226	.270	.990	−.663	.69	2.55
	(5.061)	(−1.11)	(1.18)	(2.97)	(−2.25)		
Indiana	.752	−.067	.516	.857	−.780	.57	2.09
	(2.49)	(−.29)	(2.73)	(2.373)	(−1.95)		
Kansas	4.103	−2.678	.962	7.429	−1.088	.56	1.65
	(.82)	(−1.14)	(2.34)	(1.34)	(−1.64)		
Montana[c]	5.543	−1.581	−.341	−2.543	.775	.55	1.79
	(4.60)	(−1.53)	(−1.01)	(−2.19)	(2.13)		
Nebraska	1.145	−.837	1.014	1.221	−.418	.82	4.33
	(1.37)	(−1.74)	(5.28)	(1.47)	(−1.29)		
Onio	.296	−.338	1.023	1.069	−.759	.82	3.58
	(.932)	(−1.41)	(5.41)	(2.74)	(−2.43)		
Oklahoma	1.421	−1.642	1.185	2.700	−.784	.66	1.90
	(1.01)	(−2.29)	(3.28)	(1.68)	(−1.89)		
Texas	2.905	−2.241	.947	2.809	−1.017	.85	1.22
	(2.88)	(−2.11)	(5.19)	(2.22)	(−2.64)		
Washington	1.508	−1.468	1.144	.659	−.336	.90	2.13
	(4.95)	(−6.40)	(6.96)	(1.96)	(−1.59)		

[a] The dependent variables, *ERP*, and *MAXD* are the same as in table 1. *CONST* is the constant term; *WAL* is the wheat acreage allotment; and *PERRU* is the percentage of the loan rate used in figuring diversion payments. See text for details.
[b] Spring wheat.
[c] Winter wheat.

wheat, respectively. The estimated coefficients for *DIV* are negative in all cases except for spring wheat in Montana. The t-ratios tend to be small, but the pattern of results across states seems encouraging and the magnitudes of the estimates appear reasonable. Thus, for example, for every 100 acres diverted under the wheat and feed grain programs, the acreage planted to wheat fell by twenty-two acres in North Dakota and twenty-six acres in Kansas. The estimated coefficients are strikingly similar for Nebraska, Oklahoma, Texas, and Colorado.

Turning to the quota years, the estimates for equation (3) are given in table 3. The importance of wheat allotments in determining planted wheat acreage during the quota years is remarkable. Excluding winter wheat in Montana, the estimated coefficients for wheat allotments (*WAL*) are positive for the remaining twelve cases. For eight of these twelve cases the t-ratios for *WAL* exceed 3.0. For several states the estimated coefficient is close to unity, indicating that a one acre increase in allotments was associated with a one acre increase in planted acreage.

A second conclusion is that acreage planted to wheat did not respond positively to the relative price of wheat. The coefficients for *ERP* are negative in every case except one. The t-ratios are low in the majority of cases. Simple correlation coefficients between *ERP* and each of the program variables were very low with only a few exceptions. Adding trend to the equation does not alter the pattern of unexpected signs for *ERP*. These findings may reflect the downward movement of the national average support price for wheat (loan rate) from $2.24 per bushel in 1954 to $1.30 in 1964. The negative sign for *ERP* may reflect an empirical regularity growing out of the evolution of farm policy. In any event, the hypothesis, implicit in previous work, that the acreage supply function during the quota years has the same slope as during the nonquota years would appear to have received a near-fatal blow.

Finally, although the estimated coefficients

for *MAXD* have the expected signs in most cases, the same cannot be said for *PERRU*. While we are unable to explain these results it is possible that the high correlation between *PERRU* and *MAXD* prohibited measuring the separate effects of each with much precision. On balance, however, the findings do not lend much support to the view that diversion programs reduced significantly the acreage planted to wheat during the quota years. This conclusion was also supported by further statistical work in which *MAXD* and *PERRU* were deleted from (3) and a land diversion variable was added in their place. In the revised formulation, the estimated coefficients for land diversion were negative in seven cases and positive in six. Once again, the estimated coefficients for *ERP* were mostly negative.

Implications for Future Work

Three suggestions for future supply analysis may be offered on the basis of findings discussed above. First, futures prices appear to merit consideration as an alternative to using distributed lags in modeling price expectations for economic research. Second, spatial heterogeneity and the opportunity for measuring variables with greater precision might well make disaggregation at least to the state level well worth the extra costs of data collection and analysis. Third, because farm programs change over time and may have profound impacts on the nature of supply response, it is important to structure analysis to allow for changes in relevant variables and in parameters, including elasticities, over sample periods.

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References

Cochrane, W. W., and Mary E. Ryan. *American Farm Policy, 1948–1973*. Minneapolis: University of Minnesota Press, 1976.

Dow Jones & Co. *Wall Street Journal*, various issues 1948–74.

Gardner, B. L. "Futures Prices in Supply Analysis." *Amer. J. Agr. Econ.* 58(1976):81–84.

Garst, G. D., and T. A. Miller. "Impact of the Set-Aside Program on U.S. Wheat Acreages." *Agr. Econ. Res.* 27(1975):30–37.

Hadwiger, D. F. *Federal Wheat Commodity Programs*. Ames: Iowa State University Press, 1970.

Houck, J. P., M. E. Abel, M. E. Ryan, P. W. Gallagher, R. G. Hoffman, and J. B. Penn. *Analyzing the Impact of Government Programs on Crop Acreage*. USDA ERS Tech. Bull. 1548, Aug. 1976.

Kmenta, J. *Elements of Econometrics*. New York: Macmillan Co., 1971.

Lidman, R., and D. L. Bawden. "The Impact of Government Programs on Wheat Acreage." *Land Econ.* 50(1974):327–35.

Malinvaud, E. *Statistical Methods of Econometrics*. New York: American Elsevier Publishing Co., 1970.

Tomek, W. G., and K. L. Robinson. "Agricultural Price Analysis and Outlook." *A Survey of Agricultural Economics Literature*, vol. 1, ed. L. Martin, pp. 329–409. Minneapolis: University of Minnesota Press, 1977.

Tornquist, L. "The Bank of Finland's Consumption Price Index." *Bank of Finland Monthly Bull.*, no. 10 (1936), pp. 1–8.

U.S. Department of Agriculture. *Agricultural Statistics*. SRS, 1948–1976 issues.

———. *Crop Production—Revised Estimates: 1944–1949*. BAE Statist. Bull. No. 108.

———. *Crop Values*. SRS CRB 1961–76 issues.

———. *Field Crops—Revised Estimates by States*. SRS Statist. Bull. nos. 185, 290, 384, 498, and 582.

———. *Usual Planting and Harvesting Dates*. SRS Agr. Handbook no. 283, Mar. 1972.

———. *Wheat—1978 Program*. ASCS Commodity Fact Sheet, undated.

———. *Wheat Situation*. ERS nos. WS-149, WS-158, WS-174, WS-180, WS-201, WS-205, WS-210, WS-218, and WS-226.

Weaver, R. D. *Supply and Input Choice Response by Multiple Product Firms: New Approaches*. Agr. Econ. and Rural Soc. No. 137, Pennsylvania State University, Oct. 1978.

The Structure of Production and the Derived Demand for Inputs in Canadian Agriculture

Ramon E. Lopez

The evidence suggests that an aggregate cost function and, hence, an aggregate production function for Canadian agriculture exists. Furthermore, growth in Canadian agriculture has been primarily associated with economies of scale rather than with factor-augmenting technical change. A nonhomothetic dual cost function is used to derive explicitly the system of four input demand equations (labor, capital, land and structures, and intermediate inputs) using time-series data for the period 1946–77. Estimates of the own-price elasticities and of the Hicks-Allen elasticities of substitution among the input pairs are also provided.

Key words: aggregate production function, Canada, cost function, elasticities of substitution, factor-augmenting technical change, input demand.

The purpose of this paper is to present an analysis of the structure of the Canadian agricultural production sector and its derived demand for inputs. Specifically, the emphasis is placed on the following aspects: (*a*) Estimation of a set of aggregate input demand functions and a test of whether or not these functions can be considered to reflect aggregate dual cost and production functions. In short, the aim is to test whether the estimated derived-demand functions satisfy the integrability conditions (Varian, Hurwicz and Uzawa) and, hence, whether an aggregate technology for Canadian agriculture exists. (*b*) Estimation of factor substitution possibilities (or complementarities) and in particular to test formally the hypothesis of fixed coefficients of production in Canadian agriculture. (*c*) Testing for homotheticity of the production function, in particular, whether the production function exhibits constant returns to scale. (*d*) Testing for the existence of factor-augmenting technical change.

The present study differs from previous ones of agricultural production and input demand functions in two respects. First, previous studies have explicitly derived the aggregate input demand functions and estimated them from a cost-minimizing scheme; but they have not been generally concerned whether the estimated demand functions satisfy the integrability conditions.[1] They have not addressed the following question: given a system of estimated aggregate derived-demand equations, is there necessarily an aggregate production function from which the system can be derived? Hurwicz and Uzawa have shown that a system of demand equations is integrable if, and only if, the Hessian matrix is symmetric. But the symmetric Hessian matrix means that the matrix of second partial derivatives of the cost function must be symmetric, and hence, we first test rather than impose the symmetry conditions on our demand system. If the symmetry condition is rejected, it means there does not exist an aggregate cost function and a production function underlying the input demand functions. On the other hand, if the symmetry conditions hold, it implies that the demand functions are integrable to some macrofunction. However, according to Hurwicz, symmetry implies mathematical integrability, but not necessarily economic integrability. Economic integrability of compensated de-

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[1] Binswanger (1974a) did test for symmetry.

rived-demand functions also means that the function yielded by the integration process (the macrofunction) satisfies the conditions of a cost function, i.e., negative semidefiniteness of the Hessian matrix, with respect to prices, nonnegativity, and nondecreasing in output levels. Accordingly, apart from the symmetry test we will check whether these properties are satisfied by the macrofunction underlying the derived-demand functions.

Second, the functional form used for the cost function is more general than those used by Kako and Binswanger (1974a and 1974b) and it allows for a rigorous test for a fixed-proportion production function as well as for the hypothesis of constant returns to scale and homotheticity. This functional form was used by Woodland in a study of substitution structures at a more aggregate level than ours and applied to all major industrial divisions in Canada. The function used allows simultaneous testing for constant returns to scale and factor-augmenting technical progress. Binswanger (1974b) has been able to separate the effect of biased technical change on the observed factor shares from the effect of ordinary factor substitution due to factor price changes. However, factor shares also can be affected by changes in the scale of production if the production function is nonhomothetic. Binswanger assumed a homothetic production technology, and, hence, he explained all changes in factor shares by fluctuations in factor prices and/or technological change bias. Using our more general functional form, we are able to separate and identify the effects of price changes, factor-augmenting technological change, and production levels in factor demands. Kako also assumed constant returns to scale; and, although he measured technical change biases, he did not rigorously test for neutral or biased technical change.

Following Woodland and others, we assume throughout this paper that input prices are determined in the nonagricultural sectors. This assumption appears reasonable for all inputs with the exception perhaps of land. Agriculture is a major user of the latter input, and hence its price may be endogenous. While it would be desirable to consider the endogeneity of land prices, to do so would increase the number of parameters to be estimated and add complexity to an already difficult model. The assumption that the wage rate is exogenously determined may be dubious. However, according to Lopez and MacMillan, the farm wage rate essentially follows the pattern of nonagricultural wage rates.

The Model

Diewert (1974) has shown that if there exists a continuous from above production function, $F(\mathbf{x})$, then there exists a cost function, $C(\mathbf{P}, Q)$, such

$$(1) \qquad C(\mathbf{P}, Q) \equiv [\min_{\mathbf{x}} p^T\mathbf{x} : F(\mathbf{x}) \geq Q],$$

where $\mathbf{P}$ is a vector of factor prices; $\mathbf{x}$ is a vector of factor demands; and Q is the amount of output produced. The cost function $C(P, Q)$ as defined by (1) satisfies a number of conditions: nonnegative at all prices and output levels, nondecreasing in output, monotonic increasing in prices, concave in prices, continuous and linear homogenous in prices (see Diewert 1978). This cost function is dual to a production function in the sense that it completely characterizes the economic region of the production function.

For econometric estimation we need to use a specific functional form for $C(\mathbf{P}_L, \mathbf{P}_K, \mathbf{P}_T, \mathbf{P}_M; Q)$ where L, K, T, M refer to labor, capital, land and structures, and intermediate inputs. The cost function specified is an adaptation by Parks of the Generalized Leontief (GL) cost function

$$(2) \qquad C(\mathbf{P}, Q, t) = Q \sum_i \sum_j b_{ij}\, p_i^{\frac{1}{2}}\, p_j^{\frac{1}{2}} + Q^2 \sum_i \alpha_i p_i + Q\, t \sum_i \gamma_i p_i,$$

where p_i is the price of input i ($i = L, K, T, M$), and t stands for time.

Note that continuity and linear homogeneity in prices are the only conditions a priori imposed on the cost function defined by (2). All the other conditions of a cost function, nonnegativity, monotonicity, concavity, and nondecreasing in output will depend on the actual values of the estimated parameters, b_{ij}, α_i, and γ_i. Similarly, symmetry will depend whether $b_{ij} = b_{ji}$ for $i \neq j$. We are interested in determining whether the above conditions hold at least locally for the observed sample points.

Assuming that producers take factor prices as given and using Shephard's Lemma (Diewert 1974) the cost-minimizing input demand functions are defined by

$$(3)\ \mathbf{X}_i = \frac{\partial C}{\partial p_i} = \sum_{j=1} b_{ij} \left(\frac{p_j}{p_i}\right)^{\frac{1}{2}} Q + \alpha_i Q^2 + \gamma_i Q t,$$

where $\mathbf{X}_i$ is the quantity demanded of input i ($i = L, K, T, M$).

Diewert (1971) has shown that the GL cost function corresponds to a fixed coefficient production technology if $b_{ij} = 0$ for all $i \neq j$. Hence, we can test the hypothesis that there is no factor substitution due to price changes by testing whether $b_{ij} = 0$ for all $i \neq j$. Second, it has been shown (see Diewert 1974) that the cost function reflects a constant returns to scale technology if and only if it can be decomposed as

$$(4)\qquad C(\mathbf{P}, Q) = Q\,\tilde{C}(\mathbf{P}),$$

where $\tilde{C}(\mathbf{P})$ is the unit cost function and it is a nonnegative linear homogeneous, nondecreasing, and concave function of p.

Now, from (2) it is apparent that the cost function can be represented as in (4) if and only if $\alpha_i = 0$ for all i. Furthermore, if $\alpha_i \neq 0$ then the cost function represents a nonhomothetic technology. A production function will be homothetic if, and only if, its cost function decomposes as follows (Shephard)

$$(5)\qquad C(\mathbf{P}, Q) = \psi(Q)\,\tilde{C}(\mathbf{P}),$$

where ψ is a continuous, nondecreasing function of Q. It is clear in (2) that if $\alpha_i \neq 0$ for some i, then the cost function cannot be decomposed as in (5). Therefore, if $\alpha_i \neq 0$ for at least one i, then the production function underlying the cost function will not be homothetic.

A change in the input-output ratio can be due to (a) changes in factor prices, (b) changes in the scale of production if the production function does not present constant returns to scale, (c) technological change. In equation (3), it can be easily seen (dividing by Q) that the price and production scale effects are captured by the first and second right-hand side terms. The factor-augmenting technological change effect is captured by the time variable.[2] Therefore, we can test the hypothesis of existence of factor-augmenting technical change by testing whether $\gamma_i \neq 0$ for at least one i. If $\gamma_i = 0$ for all i, then factor augmenting technical change will not exist.

It is assumed that the observed input demands are distributed stochastically about the cost-minimizing input bundles, and thus equation system (3) can be written as

$$(7)\ \mathbf{X}_{in} = \Sigma_j\, b_{ij} \left(\frac{\mathbf{P}_{jn}}{p_{in}}\right)^{\frac{1}{2}} Q_n + \alpha_i Q_n^2 + \gamma_i Q_n t + e_{in},$$

where i is L, K, T, M; n is observation in period n; and e_{in} is the disturbance for input i at observation in period n.

We assume that $E(e_{in}) = 0$, but it is unrealistic to assume that the disturbances are homoscedastic over time. In this respect we follow Parks and assume that the disturbance variance corresponding to input i is proportional to the squared output level, i.e., $V(e_{in}) = Q_n^2\ \sigma_i^2$. This assumption, although arbitrary, does not seem unreasonable, and it is convenient because if we express the factor demand equations in terms of input/output ratios by dividing (7) by Q_n,[3]

$$(8)\ \frac{\mathbf{X}_{in}}{Q_n} = \sum_i b_{ij} \left(\frac{p_{jn}}{p_{in}}\right)^{\frac{1}{2}} + \alpha_i Q_n + \gamma_i t + \mu_{in},$$

$$i = L, K, T, M$$

where $\mu_{in} = \dfrac{e_{in}}{Q_n}$ which has a homoscedastic variance equal to σ_i^2.

To test for symmetry, two variants of (8) are estimated, one without any restrictions imposed and another one imposing the symmetry restrictions, $b_{ij} = b_{ji}$. In the latter model, the disturbance vector $\mu_n = (\mu_{ln}, \mu_{kn}, \mu_{tn}, \mu_{mn})$ will be correlated contemporaneously, which implies that the vector μ_n will have a joint distribution with nonzero covariance. Moreover, preliminary estimates strongly suggested that the disturbances were autocorrelated. Accordingly, the stochastic specification is directed to consider both contemporaneous and intertemporal correlation of the errors. It is assumed that the vector of disturbances μ_n presents first-order autocorrelation and that the 4×4 matrix of autocorrelation coefficients (R) is diagonal, i.e., that μ_{in} is autocorrelated with μ_{in-1} but not with μ_{jn-1} for $i \neq j$. Thus,

$$(9)\qquad \mu_n = \mu_{n-1} R + \nu_n,$$

[2] The trend variable is a poor indicator of technical change mainly because it is unlikely that technical change will be incorporated at a constant annual rate. This problem is quite serious when the objective is to obtain exact measures of technical change. In our case, we aim only to test for the existence of technical change rather than measuring it, and hence the constant rate assumption although not entirely appropriate is less serious.

[3] Preliminary estimates showed that when a set of equations like (7) was estimated the distribution of the error terms indicated heteroscedasticity. This did not happen when (8) was estimated.

where ν_n is assumed to be independently and normally distributed with $E(\nu_n) = 0$ and covariance matrix Σ.

To estimate the parameters of equation system (8) a Full Information Maximum Likelihood (FIML) method developed by Chow and Fair, as adapted by Wales, is used.

The Data

The system of derived-demand equations (8) was estimated using annual data over the period 1946–77. The data used were the prices and quantities indices of the four inputs considered and an output index.

The output variable used was Real Gross Domestic Product of agriculture expressed in 1961 prices. Labor was measured in number of man-hours worked including hired, operator, and family labor. An average annual wage rate index was obtained by dividing the total wage bill paid in agriculture (including an estimated room and board expenditure) by the number of hours worked by hired workers in agriculture. It was assumed that the self-employed workers obtained the same wage rate as the employed workers. The aggregate "intermediate inputs" included fertilizers, seeds, feeds, fuel, and electricity used in farm production. Data on values of the different intermediate input categories were available and an aggregate divisia price index was constructed. An aggregate quantity index of intermediate materials was obtained by dividing total value of intermediate materials into the aggregate price index. A similar procedure was used to aggregate the different categories of capital flows, which included farm machinery, implements, farm vehicles, and animal stocks. It was assumed that the flows of services from the different capital categories were proportional to the respective capital stocks by considering fixed depreciation rates for each type of capital stock. A quantity index for the flow services of land and structures was obtained by using a fixed depreciation rate on the value of the stock of land and structures divided by a rental price of land as calculated by Danielson. General sources for the data were different Statistics Canada publications including the CANSIM data files. Labor data were obtained from publications 21-511, 21-202, and CANSIM. Data on land and buildings, livestock, and machinery were obtained from publications 21-003 and Danielson. Other inputs and gross agricultural output were found in publications 21-511, 61-510, 62-003, and others.

Results

In order to carry out the different tests, likelihood ratio tests were performed. The likelihood ratio test is the ratio of the maximum of the likelihood function under the null hypothesis to the maximum of the likelihood function under the alternative hypothesis. Theil showed that minus twice the logarithm of a likelihood ratio has asymptotically a Chi-square (χ^2) distribution where the number of degrees of freedom is equal to the number of restrictions imposed by the null hypothesis. Table 1 shows the estimated χ^2 values calculated for each of the hypotheses tested and the critical values at 5% and 1% level of significance (LOS) for the corresponding degrees of freedom.

The first row of table 1 shows the corresponding χ^2 for the null hypothesis that the symmetry condition holds, i.e., that $b_{ij} = b_{ji}$ for all $i \neq j$, against the alternative hypothesis of no symmetry, i.e., unrestricted values of the b_{ij} and b_{ji} coefficients. The calculated χ^2 is 6.14, which is lower than the critical values at 1% and even at 5% LOS. Hence, the null

Table 1. Chi-Square Statistics for Various Hypothesis Tests

		Critical χ^2 Values		
	χ^2 Value	Degrees of Freedom	5% LOS	1% LOS
Symmetry	6.14	6	12.59	18.55
Fixed-factor proportion	79.76**	12	21.06	28.30
Constant returns to scale	50.30**	4	9.49	14.86
Zero factor augmenting technical change	3.14	4	9.49	14.86

Note: ** denotes significance at 1% level.

Table 2. Estimates of the Derived Demand Equations (Symmetry Restrictions Imposed)

	Labor	Capital	Land & Structures	Intermediate Inputs	Output	Trend	*SEE*	R^2	*DW*
Labor	4493.42	0.848	0.035	0.349	−0.013	−2.881	0.126	0.968	2.469
	(2.534)	(4.050)	(0.247)	(2.145)	(−9.413)	(−2.528)			
Capital		−7215.020	0.371	2.473	−0.043	5.518	0.557	0.734	1.849
		(0.680)	(2.893)	(10.095)	(−6.795)	(0.670)			
Land and structures			944.320	0.218	−0.006	−0.637	0.043	0.817	1.641
			(1.392)	(2.980)	(−13.026)	(−1.409)			
Intermediate inputs				4464.970	−0.030	−3.344	0.262	0.889	2.766
				(0.943)	(9.893)	(−0.960)			

Note: Asymptotic t-values are in parentheses.

hypothesis of symmetry cannot be rejected at any reasonable level of significance. Accordingly, all further results and tests are obtained using the symmetry restrictions $b_{ij} = b_{ji}$ for all $i \neq j$ imposed. Table 2 shows the FIML estimates of the input/output equations with the symmetry restrictions imposed.[4]

A fixed proportion technology (a Leontief production function) is an extreme situation where the input-output coefficients are independent of input prices or, equivalently, that all elasticities of substitution are zero. This implies in (8) that $b_{ij} = 0$ for all $i \neq j$, which is our null hypothesis against the alternative hypothesis that not all b_{ij} equal 0. The χ^2 values are reported in row 2 of table 1 and show that the calculated χ^2 value is higher than the critical χ^2 values indicating that we can reject the null hypothesis even at 1% LOS. Thus, agricultural production involves a significant degree of factor substitution in response to price changes as reflected by a very large χ^2 value.

The hypothesis of constant returns to scale is also strongly rejected at 5% or 1% LOS. All coefficients corresponding to the output variable (see table 2) present significant asymptotic t-statistics and are all negative. This implies that as the scale of production is expanded, efficiency in the use of factors increases. This is reflected in considerable reductions in the input/output coefficients. If the production function presents constant returns to scale, then all the α_i coefficients would vanish. The high χ^2 values for the test of null hypothesis that $\alpha_i = 0$ for all i allows one to reject that hypothesis. Moreover, the fact that we reject the hypothesis that $\alpha_i = 0$ for all i implies that the underlying production technology is nonhomothetic. Homotheticity implies that the input ratios are independent from output levels. Using (7), we can specify the input ratios

$$(10)\quad \frac{\mathbf{X}_i}{\mathbf{X}_j} = \frac{\sum_j b_{ij}\left(\frac{p_j}{p_i}\right)^{\frac{1}{2}} + \gamma_i t + \alpha_i Q}{\sum_i b_{ij}\left(\frac{p_i}{p_j}\right)^{\frac{1}{2}} + \gamma_j t + \alpha_j Q},\ i \neq j.$$

It is clear that $\frac{\mathbf{X}_i}{\mathbf{X}_j}$ will be independent of the output levels if $\alpha_i = \alpha_j = 0$ for all i, j. Thus, the production function will be globally homothetic if $\alpha_i = \alpha_j = 0$. However, if α_i and α_j satisfy the following condition,

$$(11)\quad \alpha_i \frac{Q^2}{\mathbf{X}_i} = \alpha_j \frac{Q^2}{\mathbf{X}_j}\ i \neq j,$$

then it can be seen easily in (10) that the $\frac{\mathbf{X}_i}{\mathbf{X}_j}$ ratio will not be a function of Q. Obviously, condition (11) can be satisfied only locally for some input-output ratios. Notice that the input-output ratios elasticities with respect to the output scale (ϵ_{iQ}) is $\alpha_i \frac{Q^2}{\mathbf{X}_i}$ and hence condition (11) implies that such elasticities will be similar for the different inputs. We can check whether this condition was met at least approximately for some years in our sample. The fact that the values of ϵ_{iQ} for the different inputs are considerably different in all years would be an indication that homotheticity does not hold (see table 3 where the ϵ_{iQ} are reported for three years).

The χ^2 corresponding to the test of the null hypothesis of no factor augmenting technical progress is presented in the last row of table 1. The χ^2 value is not significant, and hence we cannot reject the null hypothesis. As can be

[4] The unrestricted estimates as well as different indicators regarding the intersample performance of the model are available on request.

seen in table 2, the coefficients of the trend variable are in general nonsignificant with the exception of labor. The nonrejection of the zero technical change hypothesis is quite surprising considering the general conception that technological progress in Canadian agriculture has been important, being labor-saving and capital-using. Thus, the observed decrease in agriculture labor demand and increased capitalization would reflect changes in relative prices and a nonhomothetic production function (which would bend the expansion path towards a higher capital/labor ratio as output is expanded) rather than (biased) technological change. It is interesting to point out that if we impose constant returns to scale, then the hypothesis of zero technical progress is rejected at 5% and even at 1% LOS. In this case technical change appears important, which is consistent with the conventional view and with some previous results obtained in U.S. agriculture where homotheticity was imposed. It is interesting to mention that the hypothesis of zero technical change was not rejected by Lau and Tamura when they used a nonhomothetic production function for Japanese petrochemical industry. As in our case, when they imposed homotheticity, then the technical change variable became significant.

The Own-Price Elasticities and Elasticities of Substitution

In the GL cost function the own-price elasticities, (E_{ii}) can be calculated as follows (Diewert 1974)

$$(12)\quad E_{ii} = -\frac{Q}{2X_i}\sum_{j\neq i} b_{ij}\left(\frac{P_j}{P_i}\right)^{\frac{1}{2}}, \quad i, j = L, K, T, M.$$

The own-price elasticities were calculated at each year's factor prices. Table 3 presents the own-price elasticities of the four inputs evaluated at 1948, 1965, 1977, and at the mean values for the sample. The own-price elasticities for labor, capital, land and structures, and intermediate inputs appear to be inelastic, with values ranging between −0.280 and −0.897. These results are similar to those obtained by Kako for Japan using a translog cost function although the results are not entirely comparable because he disaggregated intermediate inputs into fertilizers and others. The

Table 3. Elasticities of the Input/Output Ratios with Respect to Production Scale (ϵ_{iQ}), Estimated Own-Price Elasticities (E_{ii}), and Partial Elasticities of Substitution (σ_{ij})

	1948	1965	1977	Mean Value
ϵ_{LQ}	−0.363	−1.373	−3.702	−1.392
ϵ_{KQ}	−1.010	−0.920	−1.685	−1.013
ϵ_{TQ}	−0.600	−1.053	−1.710	−1.431
ϵ_{MQ}	−0.960	−0.870	−1.269	−0.959
E_{LL}	−0.280	−0.513	−0.897	−0.517
E_{KK}	−0.455	−0.317	−0.410	−0.347
E_{TT}	−0.464	−0.383	−0.359	−0.422
E_{MM}	−0.455	−0.344	−0.391	−0.410
σ_{LK}	1.428	1.859	2.853	1.779
σ_{LT}	0.054	0.091	0.209	0.113
σ_{LM}	0.623	0.889	1.087	0.875
σ_{KT}	0.290	0.172	0.286	0.234
σ_{KM}	2.531	1.282	1.134	1.555
σ_{TM}	1.285	0.824	0.539	0.991

similarity between own-price elasticities of labor and land is quite remarkable. Kako obtained values ranging from −0.401 to −0.465 for labor and −0.464 to −0.491 for land. The average own-price elasticities for labor obtained by Binswanger (1974b) using U.S. data was −0.911, which is somewhat higher than ours. The estimate for land was −0.336, which is slightly lower than ours.

The Hicks-Allen partial elasticities of substitution (AES) for the Generalized Leontief Cost function can be calculated as follows:

$$(13)\quad \sigma_{ij} = \frac{E_{ij}}{S_i}, \; i, j = L, K, T, M$$

where $\sigma_{ij} = \sigma_{ji}$ is the partial elasticity of substitution between input i and input j, S_i is the cost share of input i, and

$$(14)\quad E_{ij} = \frac{Q}{2X_i} b_{ij}\left(\frac{p_j}{p_i}\right)^{\frac{1}{2}}, \; i \neq j, \; i, j = L, K, T, M.$$

Notice that, in general, $E_{ij} \neq E_{ji}$ but that $\sigma_{ij} = \sigma_{ji}$.

Table 3 presents the partial elasticities of substitution among all input pairs. In general, the elasticities of substitution are all positive but quite small. All input pairs appear to be substitutes, and the highest degree of substitution occurs between labor and farm capital and between capital and intermediate inputs. It is possible that the rather high elasticity of sub-

stitution between labor and capital is related mainly to the inclusion of operator and family labor as part of the labor input component. As the number of operators and the number of farms decrease, there is a trend toward expanding the farm size and degree of mechanization.

On the other hand, the substitution between labor and land and structures is very low and, indeed, it is not significantly different from zero (notice that the coefficient $b_{L,T}$ corresponding to the cross-effect of labor and land is nonsignificantly different from zero). The elasticity of substitution between capital and land and structures also appears quite low although it is significantly different from zero. Thus, labor and land and structures would not be substitutes to each other. Another interesting feature of the elasticities of substitution obtained is that except for σ_{LM} and σ_{TM}, their values are significantly different from one. Thus, the Cobb-Douglas assumption is not supported by our estimates. Similarly, the constant elasticity of substitution (CES) is not supported by our estimates given the rather important variability of the elasticities of substitution estimated for the different input pairs. Hence, it would appear that neither the Cobb-Douglas nor the CES functional form specifications are appropriate for Canadian agricultural production.

Our estimates are quite different from those obtained by Kako for Japan's rice production, although the predominantly positive signs of his coefficients are consistent with ours. Kako obtained a higher elasticity of substitution between land and labor (ranging from 0.760 to 0.816) and a lower one between labor and capital (0.934) than our estimates. The same elasticities may be approximately compared with Binswanger's (1974b) estimates for U.S. agriculture. His estimates were 0.204 for land and labor, 1,215 for land and machinery, and 0.851 for labor and machinery.

It is interesting to determine whether our estimated-demand functions imply a well-behaved cost function satisfying the conditions of a cost function defined by (1). Three properties which may be checked are (*a*) nonnegativity, (*b*) monotonicity, (*c*) concavity in prices. Given that the GL cost function does not necessarily satisfy these properties globally, we checked them at each observation point. However, given that our $b_{ij} > 0$ for all $i \neq j$, our estimated cost function globally satisfies the concavity condition, i.e., the Hessian matrix is negative semidefinite (Diewert 1971). The nonnegativity and the monotonicity properties were satisfied at each observation. Price monotonicity is satisfied if $\frac{\partial C}{\partial p_i} > 0$ for all i, which implies that our fitted demand functions must be positive for all observations. The fitted demand values were calculated for all observations using our FIML estimates. All demand values were found to be positive. In checking for nonnegativity of the cost levels, we followed a similar procedure using the FIML estimates now substituted directly into the cost function. Thus, the estimated cost function satisfies the conditions of a dual cost function; and, hence (given that the symmetry conditions are met), one can conclude that the conditions for economic integrability are satisfied, implying that an aggregate production function for Canadian agriculture exists. Furthermore, this is also an indication that farm producers minimize costs.

Conclusions

A number of important conclusions emerged from the study: (*a*) The derived demand functions satisfy the conditions for economic integrability. This implies that an aggregate cost function and, therefore, an aggregate production function for Canadian agriculture exist. (*b*) Relative factor prices do play an important role in the determination of the demands for the different inputs. Thus, a Leontief type of production function has been rejected. (*c*) The hypothesis of constant returns to scale in Canadian agriculture is rejected. Moreover, the evidence suggests that the production function is nonhomothetic. (*d*) Contrary to the generally accepted opinion, the evidence does not support the existence of factor-augmenting technical progress. The observed reduction in the labor/capital ratio may be due to relative price and output expansion effects rather than to (biased) technological progress. The assumption of a homothetic production function is a crucial assumption when testing for technical progress. When homotheticity is imposed, the output expansion effects on input shares are incorrectly attributed to biased technological change. (*e*) An important quantitative result is that the estimated own-price elasticities of demand are all less than one in absolute value. These results are consistent with the inelastic demands obtained by Kako.

Another interesting finding is that the cross-elasticities of substitution are all positive. In particular, labor is a substitute with all other inputs with the exception of land with which there appears to be no substitution. The highest degree of substitution was found between labor and farm capital inputs.

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References

Binswanger, H. "A Cost Function Approach to the Measurement of Elasticities of Factor Demand and Elasticities of Substitution." *Amer. J. Agr. Econ.* 56(1974a):377–86.

———. "The Measurement of Technical Change Biases with Many Factors of Production." *Amer. Econ. Rev.* 64(1974b):964–76.

Chow, G. C., and R. C. Fair. "Maximum Likelihood Estimation of Linear Equation Systems with Auto-Regressive Residuals." Res. Memo No. 137, Econometric Research Program, Princeton University, 1971.

Danielson, R. S. "Three Studies in Canadian Agriculture." M.A. thesis, University of British Columbia, 1975.

Diewert, W. E. "An Application of Shephard Duality Theorem: A Generalized Leontief Production Function." *J. Polit. Econ.* 79(1971):481–507.

———. "Applications of Duality Theory." *Frontiers of Quantitative Economics*, vol. 2, ed. M. D. Intriligator and D. A. Kendrick. Amsterdam: North-Holland Publishing Co. 1974.

———. "Duality Approaches to Microeconomics." Dep. Econ. Disc. Pap. No. 78-09, University of British Columbia, 1978.

Hicks, J. R. *Value and Capital.* London: Oxford University Press, 1968.

Hurwicz, L. "On the Problem of Integrability of Demand Functions." *Preferences, Utility and Demand*, ed. J. Chipman. New York: Harcourt, Brace, & Co., 1971.

Hurwicz, L., and H. Uzawa. "On the Integrability of Demand Functions." *Preferences, Utilities and Demand*, ed. J. Chipman. New York: Harcourt, Brace & Co., 1971.

Kako, T. "Decomposition Analysis of Derived Demand for Factor Inputs: The Case of Rice Production in Japan." *Amer. J. Agr. Econ.* 60(1978):628–35.

Lopez, R., and J. MacMillan. "Econometric Analysis of the Canadian Regional Hired Farm Labour Market." Unpublished paper. University of British Columbia, 1979.

Lau, L. J., and S. Tamura. "Economies of Scale, Technical Progress, and the Nonhomothetic Leontief Production Function: An Application to the Japanese Petrochemical Processing Industry." *J. Polit. Econ.* 80(1972):116–87.

Parks, R. W. "Price Responsiveness of Factor Utilization in Swedish Manufacturing, 1870–1950." *Rev. Econ. Statist.* 53(1971):129–39.

Shephard, R. W. *Theory of Cost and Production Function.* Princeton, N.J.: Princeton University Press, 1970.

Statistics Canada. Publications 21–202, 21–003, 21–511, 61–510, 62–003, and CANSIM Data Files.

Theil, H. *Principles of Econometrics.* New York: John Wiley & Sons, 1971.

Varian, H. R. *Microeconomic Analysis.* New York: W. W. Norton & Co., 1978.

Wales, K. "Full-Information Maximum Likelihood Program: User's Guide." University of British Columbia Statistical Centre, June 1975.

Woodland, A. D. "Substitution of Structures, Equipment and Labour in Canadian Production." *Int. Econ. Rev.* 16(1975):171–87.

The Evaluation of the Benefits of Basic Need Policies

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This paper presents a method to quantify social benefits of basic need policies by (*a*) relating their definition to the degree of fulfillment of accepted social standards, and (*b*) recasting the analysis of basic need projects within the general framework of shadow pricing in cost-benefit analysis. An empirical application of this method shows that in poor countries, the attempt at upholding a standard of minimum food consumption for the poor would put substantial premiums on food production over and above world (or domestic supply) prices provided that the increased food supply results in sufficiently higher consumption for the undernourished.

Key words: basic needs, food consumption, shadow pricing, social demand, social standards.

This paper presents a theoretical framework for the analysis of market intervention policies of goods related to the satisfaction of basic human needs. While there has been recent interest in the economic literature for the evaluation of these goals and particularly of nutrition schemes, virtually all studies have attempted to appraise these schemes in terms either of (*a*) specific physical consequences or (*b*) cost effectiveness. For example, Reutlinger and Selowsky utilize a framework where cost effectiveness is defined as the fiscal cost of providing one extra calorie to a target group of consumers. Pinstrup-Andersen and Caicedo compare the consequences of income distribution policies on the calorie consumption of different income groups, while McCarthy uses an input-output framework to extend Reutlinger and Selowsky's method to multipliers' effects.

One of the main reasons cost effectiveness has been considered the natural method of evaluating alternative basic needs policies is that these policies generally are specified in terms of social standards. Given these standards, cost effectiveness assumes that each additional amount of consumption toward the promotion of the accepted requirement carries the same social benefit.

While one can easily sympathize with the simple features of the framework induced by the above assumption, there are several reasons why cost effectiveness appears to be a particularly inadequate method of choice of alternative policy options. First, the target of assuring to all consumers the satisfaction of basic needs is often not one that can be achieved within the limits of government resources or within the realm of time of the policies being examined. Second, it appears reasonable to assume that the consumers whose consumption is further from the targets should receive some priority over the ones which are already close to the requirement levels. Third, while the requirements may be an unequivocal expression of social objectives, private preferences are important to determine the extent to which (*a*) "rich" consumers tend to exceed the targets, and (*b*) "poor" consumers tend to fall below them. Fourth, cost effectiveness only permits a ranking of projects with the same effects on the achievement of the basic target needs. It does not permit comparison of projects with different effects and/or different goods and/or consumers.

The cost-benefit approach suggested in this paper relates to the evaluation of basic needs by specifying a social demand function that takes into account both private preferences and social requirements. Because the number

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of people whose consumption would fall below the requirement would itself vary with the price of the good in question, both private demand and social demand are shown to be negatively related to price. For a given income distribution, social demand elasticity is shown to be a function of (*a*) the Gini coefficient of income distribution, (*b*) the parameters of the private demand functions of the various income groups, and (*c*) the minimum per capita consumption required by the social standards.

The framework developed is similar to the one suggested by Harberger (1978) in a recent paper, with two important differences. First, Harberger proposes to use the private demand of a higher income class, as the social demand function for the poor. This implies that the social requirement would change with price according to the demand schedule of a predetermined social group whose behavior is used as a norm. Second, because he focuses on per capita rather than aggregate demand, Harberger does not consider the willingness to pay for food distribution at any given price to depend on the number of the undernourished. Thus, in his treatment, the elasticity of social demand and implicitly the social consumers' surplus are only a function of the elasticity of the income group designated as the norm. But in practice, the size of the income group below the poverty line (as designated by the nutritional requirement) is also a function of the price of food. In our analysis, the elasticity of the target group's size with respect to the price of food plays a critical role in determining both social demand elasticity and the social consumer surplus.

The plan of the paper is as follows: the next section presents the theoretical elements of the proposed framework for cost-benefit analysis of basic needs policy, with specific references to food distribution schemes. The third section discusses in more detail the characteristics of the social demand function and its relationship with private and social parameters. The fourth section explores some implications of the theoretical model developed in the first two sections for policy analysis and project evaluation. Then an empirical application to countries is presented, and, finally, some preliminary conclusions are made.

Evaluating Social Benefits of Food Distribution: The Social Demand Function

In determining the demand for basic needs, private parties may not conform to the community's standards for nutrition and health, because they lack information or access to the basic goods or because they do not fully share the standards. Furthermore, the poorest population groups may find themselves unable to achieve the standards because their incomes are too low, prices are too high, or both. In all these cases, the social and the private values placed on a given amount of a "basic need good" tend to differ; the market is then not a reliable means to maximize social benefits.

Figure 1, depicting the demand-price schedule for a typical "poor" consumer, illustrates some of the implications of the fact that private individuals may not behave according to social norms in basic need consumption. In this figure, $C\ C'$ indicates the demand curve of the "poor" consumer, R. The minimum consumption level based on society's standard, and P_m the price that would cause the poor consumer to purchase the minimum level. If actual price P_w exceeds P_m, the quantity consumed will fall short of the minimum level and private demand will be in conflict with social demand.

Consider now the curve $C_w\ C'_w$. This curve is parallel to $C\ C'$ and has the property of causing the consumer to purchase exactly the minimum requirement R at the prevailing price P_w; it is generated by transferring to the consumer the amount of additional income necessary to guarantee, given his preferences, that

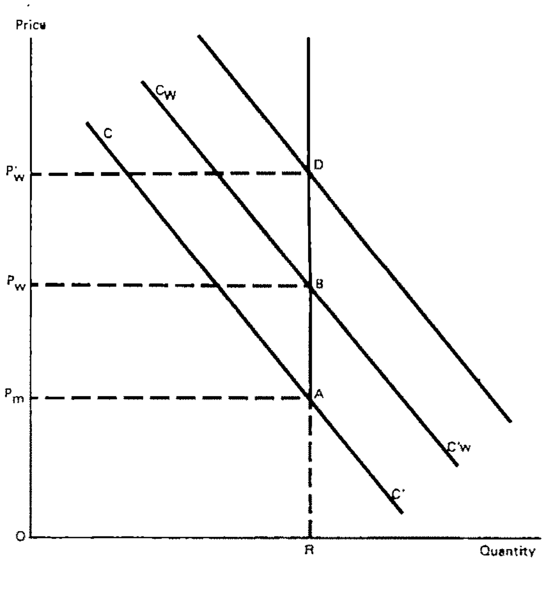

Figure 1. Demand of the poor with fixed social standards

he would buy R. As the figure clearly shows, for any price $P \geq P_m$ we can draw a similar line, but the price-quantity combination will all lie, by construction, on the vertical line ABD corresponding to the minimum requirement. The modified schedule induced by the social standard on private demand can thus be seen as the "kinked" demand curve $C'ABD$.

Figure 2 considers the slightly more complex case where the social standard itself varies with price and could coincide, for example, with the demand curve of a particular income group (Harberger's assumption). In this case the "social" requirement curve is $R\ R'$ and is assumed to be less elastic than private demand $C\ C'$. The socially modified schedule for the individual under examination can now be constructed by a similar income transfer experiment as described above and again will be a "kinked" function, $C'\ AR$ coinciding with private demand for the part of the curve below the intersection with the requirement curve $R\ R'$ and with the latter for the part above the intersection.

The comparison between the demand schedule of an individual consumer and the society's minimum consumption schedule may be useful to shed some light on the size of the per capita difference between actual and required consumption at any given price. Because it fails to incorporate information on the

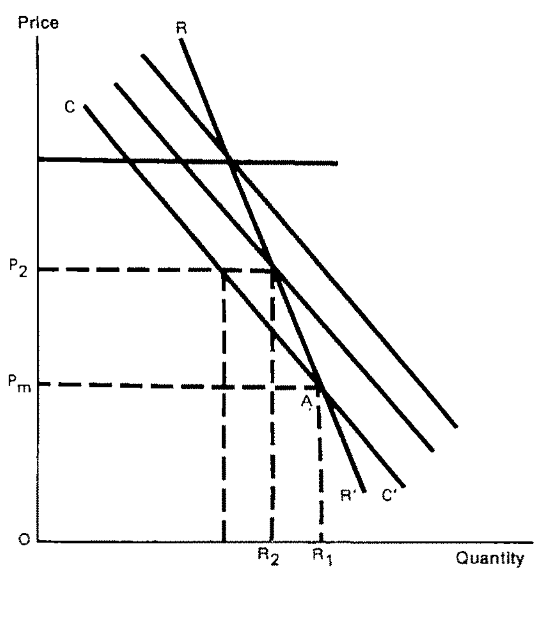

Figure 2. Demand of the poor with variable social standards

other consumers, however, the socially modified individual demand function cannot be used to measure (a) the social gains from increasing consumption up to the standard, and (b) the price that society would be willing to pay for additional units of consumption of people consuming below the requirement.

A more satisfactory way of defining a social demand function is to aggregate the modified individual schedules constructed in figures 1 and 2 and to consider the total demand function for basic needs of a given community. For simplicity, we take the case of food, measured by calorie intake, as an example of basic need good, and we assume that social standards are such that it is generally deemed desirable (a) that any individual consumes at least the amount of food necessary to satisfy some minimum nutritional standard, and (b) that, provided (a) is satisfied, individual preferences are respected. Indicating R as the nutritional standard (which for simplicity we assume invariant with respect to price and across individuals), $N(P)$ as the number of people who would be unable or unwilling to purchase at least an amount of food to achieve the standard at any given prices P, M as the size of the population, and $D(P, Y_i)$ as the amount consumed by the ith individual with income Y_i given prices P, social demand $D_s(P)$ is defined as

$$(1)\quad D_s(P) = R\,N(P) + \sum_{i=N+1}^{M} D_i(P,\ Y_i).$$

This formulation implies that an extra-agent, in addition to the private parties engaged in consumption may enter the market to require the food needed to meet the minimum social standard of the poor. While there is no need to specify who such an agent may be (the government, a charity organization, or the same "rich" consumers), expression (1) specifies the additional amount of food that such an agent, as an expression of a social norm, would transfer to the part of the population whose consumption is below the standard. The demand of this additional social agent will simply equal

$$RN(P) - \sum_{i=1}^{N} D_i(P,\ Y_i).$$

Note that R is not the socially desired minimum consumption level of the poor, but the amount of food that needs to be transferred to obtain a consumption equal to the desired level.

Being a demand schedule, social demand should be a function of prices, but also of incomes. Thus, if the agent seeking to fill the nutritional gap is the government, we may well imagine the requirement R or the tolerated nutritional gap $R - D_i(P, Y_i)$ to depend on government revenue. A similar consideration would apply to a private charity or even to a class of people above the requirement.

Although we could easily introduce into the analysis a basic needs requirement varying with the income of the government or the rich, we believe that it is not essential to the analysis or the results. Within a partial equilibrium framework, therefore, we will simply assume that the requirement is perfectly inelastic with respect to government income. This assumption, of course, is not likely to be respected except within a reasonably narrow range of implied costs and for only the most important basic need goods.

Social Demand and Private Demand

The construction of the social demand function is illustrated in figure 3. This diagram depicts the case of an economy consisting of only two "classes" of consumers: one, the poor, having the demand curve P_1D_1; and the other, the rich, with the demand curve P_2D_2. For the purpose of illustration, we assume that these two classes are equally numerous. While aggregate demand for these two classes is given by the simple horizontal sum of the two demand curves, social demand is obtained by performing the same summation only for the points below P_R, the price under which all consumers choose at least the requirement R. For all prices above P_R and below P_{2R}, the poor would consume below the requirement and social demand would be obtained by summing R (the collective requirement for the first group) with aggregate private demand for the second group. For prices above P_{2R} even the rich would consume below the social requirement, so that society's demand would simply consist of the total requirement (in this case $2R$) for the two groups of consumers.

The above procedure generates the double kinked curve FGD_3, where the two "kinks" are positioned at the prices of entrance of each group in the class of consumers "deprived" (by failing to meet the requirement) of the

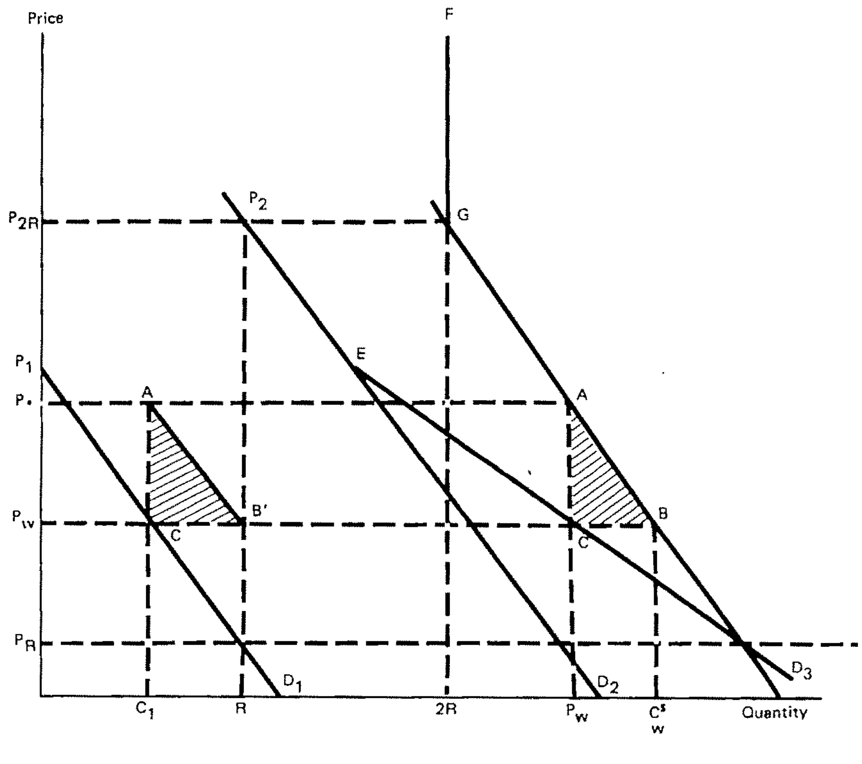

Figure 3. Social demand and private demand for two consumers

basic need good. For many classes of consumers, social demand would have many of these kinks, one for each entrance point and, in the limit for a sufficiently numerous population, it would simply be a curve convex to the origin with a vertical asymptote at the price where all the community would fail to meet the minimum consumption of basic needs and smoothly merging with private demand at sufficiently low prices.

Given a supply price P_w and assuming that the private demand curves are of the Hicks-compensated type (or alternatively accepting the approximation error of considering the uncompensated ones as schedules of willingness to pay), the social price P_* of market consumption C_w is given by the vertical distance between C_w and the social demand curve. The shaded triangle ABC represents the gain to society of a distribution scheme that would raise consumption of the poor up to the requirement level with no expenses on their part. This same triangle can be drawn in correspondence of the poors' demand curve by uniting the point representing social price P_* above the poors' consumption level at price P_w with the intersection of the requirement level with the price line P_w. Clearly, $R - C_1 = C_w^s - C_w$. Because there are only two classes of consumers, the slope of the social demand curve between the two intervention points P_* and P_w is only determined by the constant slope of the demand for one class above the requirement.

Figure 4 shows how the social gain varies with the poverty level of different groups of consumers. For each of the four classes of consumers below the requirement, social demand is obtained with the technique described for figure 3, resulting in welfare triangles whose size decreases as market demand of the corresponding income group approaches the requirement level. Aggregate social demand in the interval between shadow price P_* and supply price P_w is the weighted average of the group specific social demands, given by the downward sloping segments $A'B'$, $A''B'$, $A'''B'$.

Given the social demand as defined *i* (1), the social value or shadow price $P^*(Q)$ of a quantity Q of the commodity is given by the solution of

$$D_s(P_*) = Q, \tag{2}$$

where $P_*(Q)$ can be defined as that price at which the private demands of nonpoor (i.e., those with consumption above the requirement) just equals what is left of Q after meeting the social demand R of the poor (i.e., those with consumption below the requirement). Stated another way, $P_*(Q)$ is the price that would prevail in the market if the poor are supplied R each (out of the total supply Q) and then removed from the market.

Consider now the explicit expression for P_* in the simple case of linear demand functions

(3)

$$D_i = a_i - b_i P + c_i Y_i \qquad i = 1, 2, \ldots, M.$$

Equating social demand to market demand and solving for P_* yields

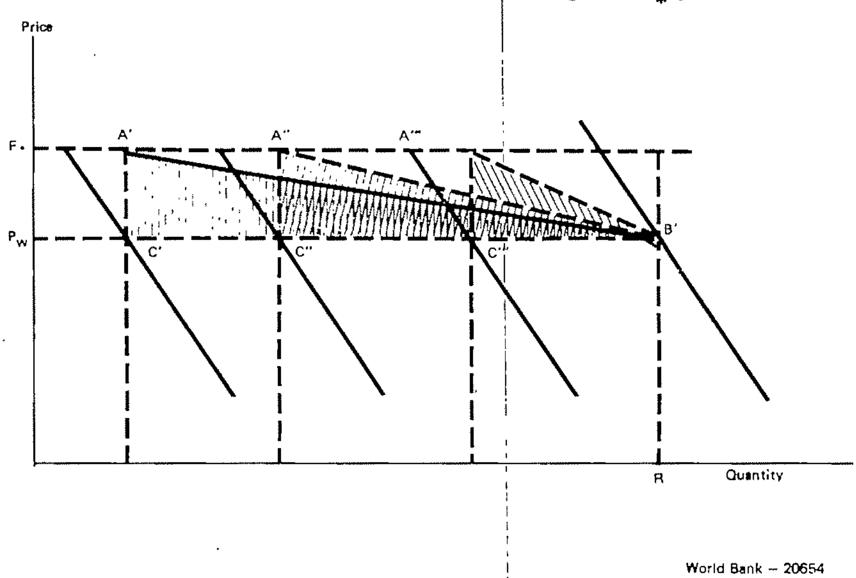

Figure 4. Social gains for different consumers below or at the basic need's requirement

$$(4)\ P_* = P_w + \left[\sum_{i=1}^{N} (R - D_i) \Big/ \sum_{i=N+1}^{M} b_i \right]$$
$$= P_w \left\{ 1 + \left[\sum_{i=1}^{N} (R - D_i) \Big/ \sum_{i=N+1}^{M} |\eta_i| D_i \right] \right\},$$

where $|\eta_i|$ is the price elasticity of demand of the ith consumer group at P_w. Social prices are thus seen to be equal to market prices plus a premium reflecting the social externality of inducing the poor to meet the minimum social requirements. This premium is directly proportional to the nutritional gap of the poor and inversely proportional to the marginal decreases in the consumption of the well nourished in response to a price increase.

The areas of the triangles in figure 4 can be expressed algebraically as follows:

$$(5)\ \Delta_i = \tfrac{1}{2} (P_* - P_w)(R - D_i) \quad i = 1, 2, \ldots, N,$$

where Δ_i indicates the social gain obtained by subsidizing the consumption of the ith undernourished consumer up to the requirement. Substituting (4) into (5) yields

$$(6)\ \Delta_i = 1/2 \left\{ \left[\sum_{j=1}^{N} (R - D_j) \Big/ \sum_{j=N+1}^{M} |\eta_j| D_j \right] \right\} P_w (R - D_i).$$

Therefore, the welfare gain from increasing the consumption of the ith malnourished group up to the requirement is directly proportional to the product of the total nutritional gap and the market value of the group specific gap, and inversely proportional to the weighted sum of the private elasticities of the groups consuming more than the requirement. Note, however, that this method of computing the gain is not "net" of the costs that might be necessary to increase the consumption of the poor. Even if the food transferred is not negotiable, the amount of food needed to cause an equal increase in consumption of the undernourished generally will be larger because the increase in real income will result in increases in consumption of other goods. The poorer the consumer, however, the smaller such a leakage because of the high propensity to consume calories or other basic need goods. Similar provisions also apply to the evaluation of the basic need components of more general transfer schemes and incomes or price subsidies.

More on the Social Demand Function

Consider again the definition in (1) and assume that the country's population is sufficiently numerous to warrant the use of a continuous distribution function $F(Y)$ for per capita income Y. Social demand can then be defined as

$$(7)\ D_s(P) = M\,[RF(Y_P) + \int_{Y_P}^{\infty} D(P,Y)\, d\,F(Y)],$$

where $D(P,Y)$ is the demand for calories of a consumer having income Y at price P, $F(Y)$ is the probability for a consumer to earn an income equal to Y or below it, and $F(Y_P)$ is the probability of earning an income less than or equal to the minimum amount required to purchase R, i.e.,

$$(8)\qquad Y_P \text{ is such that } D(P,Y_P) = R.$$

Adding and subtracting $\int_0^{Y_P} D(P,Y) d\ F(Y)$, i.e., the consumption of the people below Y_p, i.e., from (7), we further obtain

$$(9)\qquad D_s(P) = M \left\{ \int_0^{Y_P} [R - D(P,Y)]\, dF(Y) + \int_0^{\infty} D(P,Y)\, dF(Y) \right\},$$

or (social demand) = (nutritional gap) + (market demand).

Differentiating both sides of (9) with respect to P, we obtain

$$(10)\ (\partial D_s/\partial P) = M \int_{Y_P}^{\infty} (\partial D/\partial P)\, dF(Y),$$

and, in terms of elasticities,

$$(11)\ |\eta_s| = \int_{Y_P}^{\infty} \{[D(P,Y)/D_s]\}\, |\eta(Y)| dF(Y).$$

From expression (11), the elasticity of the social demand function is seen to equal a weighted average of private demand (price) elasticities $[\eta(Y)]$ of consumers above the poverty line, the weights being the ratio between private demand and social demand. Because $\int_{Y_P}^{\infty} [D(P,Y)/D_s]$ is less than or equal to one by definition, social demand elasticity will necessarily be negative and, in absolute value, less than or equal to the elasticity of aggregate private demand.

For a country whose income distribution may be described conveniently by a Pareto

function, social demand can be further specified by focusing on the function $F(Y)$. For any given income Y, the probability of an individual having income higher than Y is given by the expression

$$(12) \qquad F(Y) = [(Y/Y_o)]^{-b},$$

where Y_0 is the minimum income received and b is the Pareto income distribution parameter, which is linked to the Gini coefficient (G) by the expression

$$(13) \qquad b = (1 + G/2G).$$

Assuming for simplicity a constant elasticity private demand for a nutrient,

$$(14) \qquad D = D_o\, Y^{\epsilon}\, P^{-|\eta|},$$

we can find an explicit expression for the minimum income Y_P necessary to purchase the recommended consumption R by equating D to R in (14) and solving for Y_P,

$$(15) \qquad Y_P\,(R,P) = [(R/D_o)]^{1/\epsilon}\, P^{|\eta|/\epsilon}.$$

Substituting this result into (14), we can find the probability of an individual having income lower than Y_P from the expression

$$(16) \quad F(Y_P) = \{1 - [(R/D_o)]^{-b/\epsilon}\, P^{-(|\eta|b/\epsilon)}\, Y_o^{\,b}\}.$$

Taking the partial derivative of $F(Y_P)$ with respect to P, we obtain

$$(17) \; [\partial F(Y_P)/\partial P] = (|\eta|b/\epsilon)\; [1 - F(Y_P)]\; 1/P,$$

and the corresponding elasticity,

$$(18) \quad \eta_P = (|\eta|/\epsilon)(1 + G/2G)\;(1/\pi),$$

where G is the Gini coefficient and π the poverty ratio (i.e., the ratio between the number of people below and above R).

To find a range of plausible values for these parameters, note first that if we neglect the substitution term in the price elasticity of demand, $|\eta|/\epsilon$ in (17) will tend to approximate the budget share (m) for the basic need in question (amalgamated food or calories). Thus, a reasonable interval of variation for this ratio is 0.3 − 0.8. Assuming a Gini coefficient of 0.35, we obtain the values indicated in table 1.

Both expression (18) and table 1 show that the elasticity of the number of malnourished tends to increase rapidly as the poverty ratio π decreases and the ratio $|\eta|/\epsilon$ increases. When food expenditure accounts for a large portion of the budget, in other words, and when the number of calorie-poor individuals is only a small portion of the population, a small increase in price tends to cause a large percentage shift in the size of the deprived group. Furthermore, as expression (18) shows, this elasticity tends to be greater, the smaller is the Gini coefficient; that is, the less concentrated is the income distribution.

The interpretation of η_P is important to understand the meaning of the social demand function. Going back to expression (11), and using (12) and (14), yields

$$(19) \quad |\eta_s| = [D_o P^{-|\eta|}\, |\eta| b/D_s(Y_o)^{-b}] \int_{Y_P}^{\infty} Y^{(\epsilon-b-1)} dY.$$

Assuming $\epsilon < b$ [which is always true for plausible values of G and ϵ because it implies $G < (2\epsilon - 1)^{-1}$] and evaluating the integral in (19), and using the result in (18), we obtain

$$(20) \quad |\eta_s| = \eta_P\{2\epsilon G/[1 - G(2\epsilon - 1)]\}[RF(Y_P)/D_s].$$

In the simple exponential case covered by formulas (12) to (20), we thus have the interesting result that the elasticity of the social demand function is proportional to the elasticity of the probability of being poor, the factor of proportionality being equal to the product of (a) a term reflecting income distribution and

Table 1. Values of η_P for Alternative Values of the Budget Share (m) and the Poverty Ratio (π) (Gini Coefficient = 0.35)

m \ π	1.0	0.67	0.50	0.40	0.33	0.29	0.25
0.3	0.58	0.87	1.16	1.45	1.74	2.03	2.32
0.4	0.77	1.16	1.54	1.93	2.32	2.70	1.79
0.5	0.97	1.45	1.93	2.41	2.90	3.38	3.86
0.6	1.16	1.74	2.32	2.90	3.47	4.05	4.63
0.7	1.35	2.03	2.70	3.38	4.05	4.73	5.40
0.9	1.54	2.32	3.09	3.86	4.63	5.40	6.18

income elasticity, and (b) the ratio between food needs of the poor and total food needs. For any given income distribution and Engel coefficient, therefore, the smaller is η_P, the smaller will be the absolute value of social demand elasticity. In other words, society will be prepared to pay a higher price to subsidize consumption of the poor, (a) the higher is the proportion of the poor over total population, (b) the higher is the proportion of the consumer's budget spent on food, and (c) the more unequal the country's income distribution.

Although only a fixed minimum requirement has been postulated, the definition of social demand therefore implies a social externality plausibly varying with the size of the target group, the importance of food expenditure and income inequality. It is clear that the social gain to raising the consumption of the undernourished depends on the degree by which the consumption of the upper income group lies above the minimum standards. Social demand is thus a function of private tastes and income distribution variables.

Empirical Examples of Social Demand Analysis

In order to estimate the elasticities of social demand and the social gains from meeting the calorie requirement of the undernourished, private demand functions for calorie intake have been estimated for a set of six very poor countries chosen mainly on the basis of the availability of statistics on food consumption by expenditure classes. These countries are Bangladesh, India, Indonesia, Morocco, Pakistan, and Sri Lanka. For each country, the average quantities of the various food items consumed by households in each income group have been converted to calorie intake levels using Food and Agriculture Organization (FAO) calorie conversion tables and the percentages of the population consuming at various calorie intake have been estimated.

In table 2, the fitted regression equations on the household consumption data for the six countries are given. A semilogarithmic function is used as it traced the lower calorie intakes more closely than alternative functional forms and conformed to the Engel curve relationship. In order to introduce the price effect in the demand function, a price elasticity reflecting the income term in the Slutsky decomposition of the price response is introduced by income class by weighting the in-

Table 2. Calorie Regression Equations

Bangladesh	$C = -1779 + 851\ LnY$ (8.0)	$R^2 = 0.97$ $N = 11$
India	$C = -2199 + 1135\ LnY$ (20.1)	$R^2 = 0.99$ $N = 9$
Indonesia	$C = -5659 + 937\ LnY$ (12.9)	$R^2 = 0.98$ $N = 10$
Morocco	$C = -6246 + 1343\ LnY$ (13.0)	$R^2 = 0.85$ $N = 14$
Pakistan	$C = -231 + 603\ LnY$ (13.1)	$R^2 = 0.99$ $N = 10$
Sri Lanka	$C = 479 + 447\ LnY$ (7.6)	$R^2 = 0.99$ $N = 6$

Note: C is the daily calorie intake per capita weighted by the square root of the sample population proportion per class; Y, monthly expenditures weighted by the sample proportions; Ln, indicates natural logarithm of the variable; and N is the number of observations. The regressions are weighted by the square root of the sample proportions to compensate for heteroscedasticity introduced by the varying sample sizes used between expenditure classes.

come-class-specific income elasticity by the ratio of food expenditure to total expenditures.

Because the estimated functions are based on overall consumption data for wide income groupings of large and diverse countries, the following exercise is presented for purposes of illustration more than as a set of empirical findings. To convert the estimates of private demand into estimates of social demand, a social norm for the basic need, in this case food intake or energy (calorie) level, must be established. This social norm, although controversial and to some extent arbitrary, does have some consensus in the case of calories or at least its general range. An FAO/WHO expert committee established calorie intake standards for an average reference man and woman weighing 65 and 55 kilograms for moderate levels of activity at 3,000 and 2,200 calories per day, respectively. Because the average body weights and sex and age distribution of the population are different between countries of the sample, these average requirements range between 2,450 for Morocco, to 2,110 for India.

These estimates assume that each individual has a calorie requirement that corresponds to the average reference man or woman. However, it has been shown that the physiological requirements vary between individuals and over time thereby introducing a stochastic element into the specifications of an aggregate calorie requirement. Following Sukhatme (p. 1383), if we specify for this variation a normal

distribution with a variance σ^2 and a mean μ, the condition of undernutrition may be represented as a calorie intake level below $\mu - 2\sigma$. However, because only scanty evidence exists for estimating σ, the setting of the lower bound for the calorie requirements remains mainly arbitrary. For the purposes of this paper, the FAO/WHO calorie requirement is lowered by 10% or approximately 200 calories to estimate the number of people undernourished and hence the size of the target population. Later, a sensitivity analysis will be conducted on the influence of various norms for calorie intakes on the social gains of a basic needs policy. In table 3, the size of the target population, the level of private demand and social demand are given for the base year of the consumption survey.

Using the estimated calorie demand functions and the expenditure distributions, we have calculated the private and social demand elasticities and social gains from a distribution system that provides sufficient food for the entire population to at least consume the social norm calorie standard. Because of the aggregate nature of the estimates used, these elasticities and social gains results should be construed as approximate and are presented mainly to demonstrate the methodology.

As shown in table 4, the elasticities of social demand are low, varying from nearly 0 for Pakistan to 0.2 for India. The elasticities of the size of the target population are relatively high, ranging from 1.1 to 1.5. This difference in elasticities can be understood by referring to equations (18) and (20). As seen from these equations, the elasticities of the target population are directly proportional to the ratio of the number of people consuming above the calorie requirement to those consuming below the calorie requirement. If the calorie standard were raised, these elasticities would become lower, especially in the case of Pakistan, where the number of people defined as undernourished by the calorie standard is highly sensitive to the standard that is chosen. (Note that the elasticity of social demand is directly proportional to the elasticity of the size of the target population.)

The final columns in table 4 give the ratios on the shadow price to international prices of food distributed to the undernourished and the social gains from a food distribution system that would meet the basic food needs of the population. As shown in this table, this ratio ranges from 1.0 to 3.3 (with the exception of Bangladesh, which presents an extraordinary case and has a ratio that is very high at the accepted calorie social norm), indicating that in project analysis food production should carry a higher value in social benefit cost analysis for countries with widespread undernutrition by possibly a factor of one and one-half to three times, depending on the country, the elasticity of private demand, the extent of undernutrition, and the amount of additional food that will be directly distributed or will "trickle down" to the poor.

In the last columns in table 4, the aggregate social gains and per capita social gains of a food distribution system that meets the needs of the target population are shown. These social gains vary from \$954 million per annum for Bangladesh to \$16 million per annum for Pakistan. Sri Lanka shows no significant portion of the population (as measured by household consumption data) consuming below the calorie requirement. If evaluated on a per capita basis, Bangladesh with significant per capita deficits and large target populations is shown to receive the larger per capita gains from an expanded food distribution system that tends toward fulfilling the calorie requirement of the target groups. As indicated

Table 3. The Size of the Target Population, Private, and Social Demand in the Base Year

Country	Year	Target[a] Population		Private[b] Demand	Social[b] Demand
		(millions)	(% of population)	(millions metric tons)	
Bangladesh	1974	48.5	64	15.3	16.6
India	1973–74	152.8	26	137.0	146.0
Indonesia	1976	58.3	44	27.9	30.1
Morocco	1971	6.1	40	4.0	4.3
Pakistan	1971	37.9	58	13.9	14.2
Sri Lanka	1970	~0	~0	2.9	2.9

[a] The target population is defined as the population with consumption below the calorie requirement.
[b] Calories converted to grain equivalents at 3.5 million calories per metric ton.

Table 4. The Elasticities of Private and Social Demand and the Social Gains from Intervention[a]

Country	Base Year	Elasticity of Private Demand	Elasticity of Social Demand	Elasticity of Target Population	Ratio of Shadow Price to International Price of Food	Social[b] Gains	Social Gains[b] Per Capita	Social Gains per Capita of Population Consuming Below the Calorie Requirement
						(US$mil.)	($/Capita)	($/Capita)
Bangladesh	1974	−0.32	−0.10	1.3	6.30[c]	95.4	12.0	19.6
India	1974	−0.38	−0.18	1.6	1.15	148.1	0.25	0.7
Indonesia	1976	−0.36	−0.16	1.2	1.75	232.4	1.8	4.0
Morocco	1971	−0.35	−0.17	1.1	1.65	28.7	1.9	4.7
Pakistan	1971	−0.17	−0.06	1.5	3.35	116.2	1.8	4.4
Sri Lanka	1970	−0.11	−0.11	0.0	1.0[d]	2.1[d]	0.2[d]	0.3[d]

[a] Calculated for the social norm of 90% of the FAO/WHO calorie requirement for an average reference individual with the exception of the social gains calculations for Sri Lanka which is calculated at 100% of the calorie requirement.
[b] At a price of grain of $277/mton.
[c] Approaching very high levels at the social demand curve as over 60% of the population is consuming below or near the calorie requirement.
[d] Equals the market price of food as nearly none of the population is consuming below 90% of the calorie requirement; the social gain calculations are for achieving 100% of the FAO/WHO calorie standard.

by equation (6), the per capita social gains of any country or expenditure class increases with the degree of the deficit and the difference between the social value of food and the market place. Hence, the social gains are a combined index of the degree of the deficit and the numbers of those with calorie intakes below the requirement.

The elasticity of social demand, the shadow price to international food price ratios, and the per capita social gains all can be considered indicators of absolute poverty, combining measures of the size of the target group with measures of the size of the poverty gap. The framework for the combination is provided by the demand-price correspondence and by a simple assumption on social standards. It should be emphasized, however, that while these standards are largely arbitrary, the measures constructed do not appear to be overly sensitive to the level of the standard set for basic need except at the extremes, where the standard is high and places more than 60% of the population in need or when it is low, indicating that nearly all of the population have achieved the standard. This is important in the case of food as the FAO/WHO calorie requirement is the recommended intake estimated on the basis of the average intake of a healthy, moderately active person of a given population and, as a consequence, has been criticized for being an unrealistically high line to measure undernourishment. As table 5 shows, only as the calorie requirement is lowered (raised) such that nearly all the population is above (below) the social norm does the elasticity of social demand show a noticeable sensitivity. Within these bounds, the shadow price to international food price ratios and the social gains per target member remain at about the same orders of magnitude. Nevertheless, the importance of establishing a consensus on a social norm in the evaluation of a basic needs policy is apparent.

An alternative possibility for reaching such a consensus is to use the criterion that some percentage, for instance, the bottom 30% of the population, are to reach some minimum level of basic needs, e.g., the level at which the top 70% of the population are above. The particular percentile level that is chosen could depend on the degree of current deficits, sizes of the target populations, and the commitment of the society to the alleviation of poverty.

Reference to table 6 would indicate that the

Table 5. Sensitivity of the Elasticity and Social Gains to the Social (Calorie) Norm

Country	Elasticity of Social Demand	Elasticity of Target Population	Ratio of Shadow Price to International Price of Food	Target Population	Social Gains Per Target Population
Social Norm				(million; %)	($/Capita)
Bangladesh					
100% *R*	−0.10	1.3	6.30	48.5 (64%)	19.6
95% *R*	−0.17	1.9	1.60	36.8 (48%)	1.9
90% *R*	−0.23	2.8	1.15	24.5 (32%)	0.4
India					
100% *R*	−0.18	1.6	1.15	152.8 (26%)	0.7
95% *R*	−0.23	2.2	1.10	114.0 (19%)	0.4
90% *R*	−0.32	3.3	1.05	81.2 (14%)	0.2
Indonesia					
100% *R*	−0.16	1.2	1.75	58.3 (44%)	4.0
95% *R*	−0.18	1.4	1.35	48.6 (37%)	1.6
90% *R*	−0.36	1.8	1.20	38.9 (30%)	0.7
Morocco					
100% *R*	−0.17	1.1	1.65	6.1 (40%)	4.7
95% *R*	−0.22	1.3	1.40	5.3 (34%)	2.7
90% *R*	−0.27	1.5	1.25	4.4 (29%)	1.5
Pakistan					
100% *R*	−0.06	1.5	3.35	37.5 (58%)	4.4
95% *R*	−0.12	3.8	1.05	15.6 (24%)	0.2
90% *R*	−0.17	—	1.00	0.0 (0%)	0.0

Note: *R* is the FOA/WHO caloric requirement adjusted to account for individual variability.

social norm based on 30% being at least above the basic needs level achieved by 70% of the population would vary from about 90% for Bangladesh and Indonesia, to 100% for India, of the calorie requirement adjusted for individual variability. At these levels of attainment of basic needs, the conversion ratio of food becomes approximately 1.1 to 1.2 for the countries of the sample (excluding Sri Lanka). The social gains per capita of the target population would range between $0.3 and $1.5 per capita depending on the severity of the calorie deficits of these lower 30% of the population. Targeting basic needs policy to attaining a minimum standard for the bottom percentile of the population appears to result in conversion ratios that have some uniformity across these very poor Asian countries and results in greater stability for social gains from establishing an international social norm. This relative standard approach also is likely to represent a more realistic objective in the short term for governments of many countries with extensive undernutrition, than does the attempt to base the evaluation of benefits on an international social standard related to absolute poverty levels.

Some Conclusions

This paper has presented a theoretical framework and some empirical results to estimate the benefits from projects increasing the sup-

Table 6. Elasticity of Social Demand and Social Gains of Meeting the Basic Food Needs of Lower 30th Percentile of Population

Country	Social (Calorie) Norm	Elasticity of Social Demand	Elasticity of Target Population	Ratio of Shadow Price to International Price of Food	Social Gains per Target Population ($/Capita)
Bangladesh	89% *R*	−0.23	2.3	1.15	0.4
India	100% *R*	−0.18	1.6	1.15	0.7
Indonesia	90% *R*	−0.36	1.8	1.20	0.7
Morocco	90% *R*	−0.27	1.5	1.25	1.5
Pakistan	96% *R*	−0.12	3.7	1.08	0.3

ply of necessities to needy groups of individuals. Aside from the characteristics of the measures developed as normative indicators of income distribution, the analysis presented provides a framework and hints of empirical values for the benefits of food distribution and production projects. In all the countries considered, our results suggest that any attempt at upholding a standard of minimum consumption for the poor would put substantial but reasonable premiums on food production over and above world prices provided that the increased food supply results in higher consumption for the undernourished.

Given these results, it is important to underline some of the implications and limitations of our model for project evaluation. First, our definitions of social gains and social demand price closely follow Marshall's definition of consumers' surplus as stated in the *Principles*:

> . . . the price which a person pays for a thing can never exceed, and seldom comes up to that which he would be willing to pay rather than go without it: so that the satisfaction which he gets from its purchase generally exceeds that which he gives up in paying away its price; and he thus derives from the purchase a surplus of satisfaction. The excess of the price which he would be willing to pay rather than go without the thing, over that which he actually does pay, is the economic measure of this surplus satisfaction. It may be called consumers' surplus. (p. 124)

Second, the departure from border price suggested by our estimated conversion factor is subject to the same caveat valid for income distribution weights in project evaluation, that is the political situation must be such that the increase in the standard of living of the poor cannot be obtained via a cheaper tax-transfer mechanism or a better project. Third, the cost for making the additional amount of food available to the undernourished must of course be considered and explicitly in appraising food projects.

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References

Harberger, Arnold C. "On the Use of Distributional Weights in Social Cost-Benefit Analysis." *J. Polit. Econ.* 86(1978, Supplement):S87–S120.

———. "Basic Needs versus Distributional Weights in Social Cost-Benefit Analysis." Mimeographed. Washington, D.C.: World Bank, 1978.

Knudsen, O., and P. L. Scandizzo. *Nutrition and Food Needs in Developing Countries.* Washington, D.C.: World Bank Staff Work. Pap. No. 328, May 1979.

McCarthy, D. F. "Present Programs and Identification of New Policy Options: Pakistan." Mimeographed. International Nutrition Policy and Planning Program, Massachusetts Institute of Technology, Aug. 1977.

Marshall, A. *Principles of Economics*, 9th ed. New York: Macmillan Co., 1961.

Pinstrup-Andersen, Per, and E. Caicedo. "The Potential Impact of Changes in Income Distribution on Food Demand and Human Nutrition." *Amer. J. Agr. Econ.* 60(1978):402–15.

Reutlinger, Shlomo, and Marcelo Selowsky. *Malnutrition Remedies.* Washington, D.C.: World Bank Staff Work. Pap. No. 267, July 1978.

Reutlinger, Shlomo, and Marcelo Selowsky. *Malnutrition and Poverty: Magnitude and Policy Options.* Baltimore, Md.: Johns Hopkins University Press, World Bank Staff Occ. Pap. No. 23, 1976.

Sukhatme, P. V. "Assessment of Adequacy of Diets at Different Income Levels." *Econ. and Polit. Weekly*, Special No., Aug. 1978.

A Health Care Systems Model for Nonmetropolitan Areas

James W. Dunn and Gerald A. Doeksen

A health systems model allowing analysis of multiple services including spatial and monetary considerations is presented. Several behaviorally reasonable objective functions reflecting possible goals of the health planner are minimized using mixed integer linear programming. Under the different objective functions, the values of these functions increased little from their optimal value. Sensitivity analysis showed the solution to be quite sensitive to assumptions about migration and treatment practices while birth rates and travel costs have less impact. Use of the model is aided by health planners' use of data at their disposal.

Key words: health system planning, linear programming, mixed integer, rural health.

Health care planning has been required by law since the passage of the Hill-Burton Act in 1946. More recently the National Health Planning and Resource Development Act (PL 93-641) created health systems agencies (HSAs) in each state which are responsible for establishment and implementation of a health system plan and for approval of certain contracts and grants. These agencies do health planning at the state and substate level and advise local decision makers on health planning.

Intelligent health planning requires an understanding of the effects of changes in health service facilities on various groups. The creation of HSAs acknowledges that local health service investments often have impacts beyond the local area. In addition to impacts beyond the local area, investments in one service may affect the usage of other services. Evaluation of these regional impacts on several services is complex, further complicated by different measures of satisfactory health system performance. The complexity of the evaluation process makes it difficult to do without some tool to estimate the effect of an investment. This paper presents such a tool.

The objectives of this paper are: (*a*) to present a model for a regional health care system that includes several services, and which allows comparison of different goals, including those reflecting both spatial and pecuniary motivations; and (*b*) to demonstrate the application of this model in evaluating the difference between conflicting health care goals.

The Model

Researchers, such as Shuman and Wolfe, have stressed the need for a model that incorporates alternative objective functions reflecting the actual goals of the health decision maker. In Oklahoma, the Health Systems Agency specified low cost, availability, and accessibility as major rural health goals (Van Wagner). These objectives may not be attained simultaneously, especially in sparsely populated areas where satisfactory accessibility and low cost may be conflicting goals. Recognizing this, several objective functions have been developed, which incorporate one or more of these goals and which have a behavioral basis. They are (*a*) the sum of all patient's service and transportation costs, (*b*) the total miles of patient travel, (*c*) a quadratic function of patient travel, and (*d*) the sum of the patient's direct costs assuming a 75% coinsurance scheme for the costs of health services.

When these measures are minimized, the first and fourth objective functions address cost from the patient's perspective. The fourth

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is an attempt to reflect the importance of third party payments in reducing the marginal costs of health care. Measures (*b*) and (*c*) are related to the accessibility goal. Availability is never addressed directly because all services included in the model are available, although possibly at considerable cost and distance. These objective functions, in addition to being consistent with the goals of the Oklahoma Health Systems Agency, are consistent with certain commonly held beliefs regarding the behavior of health demanders. Because the users determine the usage pattern subject to the actions of the planners, this behavioral basis is necessary for valid modeling.

Several services are considered simultaneously so that the interactions between these services may be included in determining the optimal solution. An interaction of particular importance omitted by separate modeling of physician's services and hospital services is the limitation which physician choice places upon hospital choice and treatment prescriptions (Lubin et al., Feldstein; Smallwood, Sondik, and Offensend). An example of this important interaction in rural areas involves referral of rural residents to specialists in a more populous area. Hospitalization for treatment under such a specialist will be in a hospital convenient to the physician, not to the patient. Also hospitalization in a large, specialized facility will often require a follow-up physician's office visit to the city in which this facility is located.

A spatial equilibrium model using mixed integer linear programming with the alternative objective functions is constructed for solution of each problem. Linear programming is chosen because it has the capacity of handling a large problem for low cost, while still including most of the appropriate features of reality. The mixed integer variation is used solely to evaluate proposed new investments, and does not increase the solution cost prohibitively if a limited number of such investments are considered. This option allows the limitation of investment in new facilities and recruitment of additional physicians to integer units, rather than the continuous units required by ordinary linear programming.

The individual services considered have been modeled by researchers in the past. For example, Duncan and Heady used linear programming to model a nonmetropolitan hospital system for north central Iowa, and Daberkow and King used the branch and bound algorithm to determine the optimal location of ambulance services in northern California. These models have included the availability of other services as constraints but have not allowed for joint optimization which is important, given the joint demand decisions for certain services. Additionally, these models have not made allowances for alternative, and perhaps conflicting, goals.

The purpose of this model is to provide a normative measure of health system effectiveness by finding the optimal system for each objective function. However, it has positive value insofar as its simulation of behavior in the health system (*a*) duplicates actual behavior, or (*b*) provides information regarding potential system behavior not available to health planners from other sources. A model's value as a positive tool is substantiated through validation (Naylor). However, in the area of health system behavior, so little raw information is available that empirical validation is not possible. Where such information is available it is utilized, but, in general, any validation is of the rational variety where the validity of the answers is dependent upon the validity of the assumptions underlying the model. The relationships incorporated in this model that require assumptions regarding actual behavior are believed to be consistent with the existing literature on the relationships in the health system, and any parameters associated with these relationships are believed to be the best available.

The General System

An overview of the operation of the model (see description in Dunn 1977) is shown in figure 1. The system is viewed as having two major sectors, a supply sector and a demand sector. Each sector has spatial differentiation. Within each sector interactions occur which determine the service mixture supply and demand. Using this information the programming model determines the spatial pattern of demand satisfaction.

In the demand sector population characteristics are used to generate service demands. Population statistics are the raw data for the incidence model. These population statistics can be either supplied externally or estimated from prior data using a population prediction model. The incidence model then multiplies the incidence of various ailments for each subset of the population by the size of these popu-

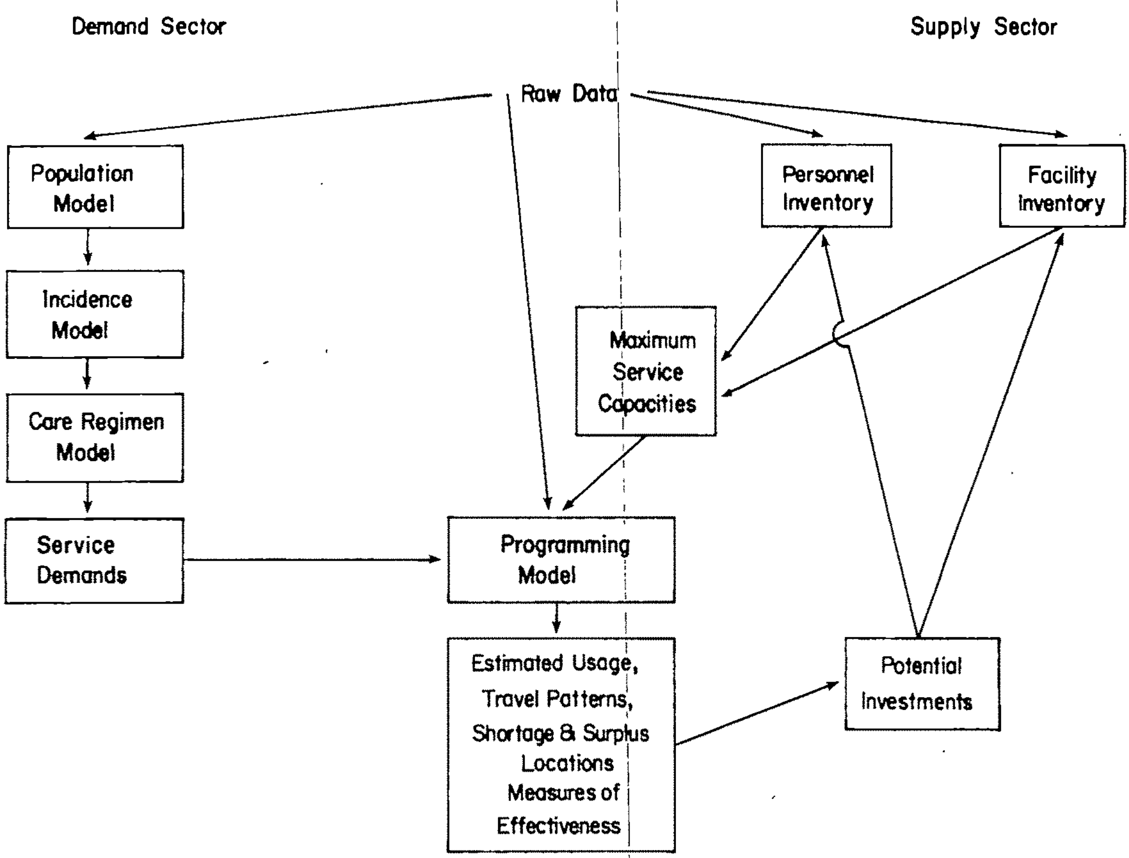

Figure 1. Overview of the solution process

lation subsets, yielding the expected incidence in cases per year. For example, suppose a community has forty men from ages 45–64. This population group has an average incidence of circulatory system problems requiring hospitalization of 40.6 cases per 1,000 population per year. Therefore the forty men in this group in location A would be expected to have 1.624 cases of circulatory system problems per year. The care regimen model associates the incidence of an ailment with a treatment prescription, specified in units of each type of health service required per case of that type by a patient of that type. This yields an expected annual demand for each type of health service by the residents of each location.

The role of price in the level of health care demanded is a source of disagreement between economists and health care providers. Health care providers contend that health care is price independent, while economists contend health care is price responsive. Joseph, in his survey of the empirical research on the demand for health care, found price explained a relatively small amount of the variation in the demand for health care. The data necessitated extension of this small effect to an assumption of no effect. In this model, price is not a determinant of the quantity of health care demanded. A particular ailment calls for a particular care regimen and the demander has no choice in its composition. However, residents choose the suppliers of the services in this regimen, subject to any constraints imposed by their needs for accompanying service, and this decision is based on the criterion implied by the applicable objective function, which may be cost minimization. Therefore, relative price is not a determinant of the quantities of different health services demanded, but it may affect the choice of supplier of particular services.

In the supply sector, the stocks of facilities and personnel in each location are translated into maximum supplies of each service for each supply location. These capacities are constraints for the programming model.

The programming model combines the service demands with the supply availabilities and generates estimated usage of these facilities for each objective function. In addi-

tion to estimated usage, the programming solution also provides travel patterns for patients seeking health care, shortage, and surplus locations, and measures of effectiveness. This information may suggest actions to better balance local supplies and demands, such as potential investments. These proposed investments are processed through the supply sector model to generate adjusted capacities. The programming model is then used to evaluate these proposed investments for each objective function using the various measures of effectiveness. The mixed integer capability allows choice between several remedies to a single problem and simultaneous consideration of several related investments.

Model Application

The model will be demonstrated using a health planning area in northwestern Oklahoma. Five interrelated services are included in the analysis: (*a*) ambulatory care, or physician office visits; (*b*) ambulance service; (*c*) emergency room service; (*d*) primary hospital care days; and (*e*) specialized hospital care days, a combination of secondary and tertiary care days.[1] Were better data available, separation of secondary and tertiary treatment would be preferred. The model is run for each of the four objective functions such that the demand for the five services from the twenty-seven demand locations are satisfied by forty-six supply locations. The supply locations include three locations not in the study area but often used by area residents, Oklahoma City, Amarillo, and Wichita.

Capacity and Interaction

The capacities of health service facilities are important data of the model. Since the demand for health services is irregular, the effective average capacity and the apparent capacity are not the same. Therefore, for hospitals and ambulances a probabilistic method was used to determine average capacity. This involves a queuing theory approach where the maximum average capacity is the mean associated with the maximum allowable probability of a patient requiring service when all available facilities are in use. For hospitals, the probability used was 0.0013, which the Oklahoma Health Planning Commission uses for its estimates of the adequacy of hospital size (Oklahoma Health Planning Commission). That is, the probability that a patient would be turned away cannot exceed 0.0013. For ambulances, an arbitrary probability of 0.0025 was used. Physician capacity was set at 6,500 office visits per year. While some physicians may see more patients, this figure is representative of patient loads for rural physicians (Cordes). Cordes's work is the basis for capacity limitations on other physician's activities, such as hospital visits and emergency room visits. No restriction was imposed on either emergency room visits or on the mix of primary and specialized care days in those hospitals providing both services. Should either of these assumptions be unreasonable, a more restrictive assumption would be necessary.

The interaction between services requires a matrix of amounts of related services accompanying a unit of each service. The coefficients in this matrix are based on information from Cordes; Schonfeld, Heston, and Falk; and from records of several ambulance services in the area in question.

Data Requirements

This model requires data that are available to health planners. The population model uses census data to generate population projections for the period to be modeled, producing estimates of population by cohorts for each demand location. The population cohorts estimated are disjoint subsets of the total population with divisions by sex and age groups, e.g., male 45–64 years. The incidence model uses the mean incidence rate in Oklahoma for the eighteen ailment categories, defined by the National Center for Health Statistics and used in the Blue Cross-Blue Shield record keeping system (May, Doeksen, Green). The care regimen model translates these cases into demand for services using mean hospital stay and percentage of patient days for each ailment requiring primary hospital care or more specialized hospital care based on Oklahoma treatment patterns. The incidence and care regimen models' functions are combined for physician visits, ambulance calls, and emergency room visits because available data for

[1] Primary hospital care involves those basic services of limited complexity available at most hospitals. Secondary care services are of a greater level of complexity and require specialized equipment and personnel which is generally not available in hospitals with fewer than 100 beds. Tertiary care services are of a high complexity and require very high skill levels of personnel and extensive supporting equipment. Tertiary care is usually available only in large hospitals.

these functions are combined (May, Doeksen, Green).

Costs of hospital care are estimated from financial records for a sample of Oklahoma hospitals. The cost per patient day (*COST*) is regressed on the number of services offered (*SER*) and the inverse of the occupancy rate (*OCC*) obtaining:

$$(1)\quad \underset{(11.58)}{COST = 25.72} + \underset{(0.414)}{2.833\ SER} + \underset{(2205)}{11664\ (1/OCC)}, \quad R^2 = 0.726$$

where standard errors are in parentheses.[2] With this equation used to generate the cost of a uniform primary care day, we derive the average cost of a specialized care day by utilizing hospital costs and stays by ailment categories (Dunn, pp. 84–88). Emergency room charges also are estimated using the hospital financial records mentioned above. Physician fees are based on American Medical Association national estimates and vary with community size. The Oklahoma Health Systems Agency considers these estimates to be representative of fees in Oklahoma (Van Wagner). Ambulance charges have two components, a base charge and a mileage charge. Doeksen, Frye, and Green suggest $25 base charge and $1 per mile as reasonable fees for a rural ambulance system (p. 11). A higher base charge is used for the two largest municipal ambulance services. In all cases, confidentiality was a problem, which it would not be for a health planner. Because a health planner is supplied with actual costs and should include these costs in the decision process, actual costs for each supplier could be used rather than estimates.

[2] Cost curves for hospital care have been estimated many times, with wide variations of results between studies; of particular interest is the inconsistent findings about economies of scale. Berki reviews many of these studies and concludes that no answer has been found. Other versions of the above cost equation reflected this.

Results

As specified in the objectives, the model may be used to estimate the impact of many changes in the health care systems, both structural and behavioral, on future system performance. Some of these uses of the model are demonstrated below.

The optimal solution for each of the alternative objective functions was obtained for 1975 to allow comparison of these solutions with the limited data on actual system behavior. The values for each objective function and certain other values when each objective function is minimized are found in table 1. It is apparent in all cases that the percentage changes that occur when different objective functions are used are quite small. This occurs because the major portion of health care activity is conducted locally under all the objective functions. Differences between solutions involve utilization of other than the nearest supplier of a service for one of the objective functions.

The optimal solution when total cost is minimized is presented first and solutions using other objective functions are compared to this. In the minimum total cost solution, some patients traveled beyond the nearest hospital to receive primary hospital care in thirteen of the sixteen counties. The movements corresponded closely with actual patient movements in the system (Oklahoma State Health Planning Agency). Estimated hospital patient days correspond very closely to actual patient days for the region as a whole, a positive reflection on the estimates of the demand model. The estimated usage of individual hospitals varied more, suggesting

Table 1. Comparison of Alternative Objective Functions for 1975

	Minimize Total Cost	Minimize Patient Travel	Minimize Squared Travel	Minimize Variable Cost
Total cost ($)	76,506,000	76,651,000	77,045,000	76,734,000
Patient travel (miles)	85,099,000	83,497,000	85,454,000	83,510,000
Squared travel (miles)²	2,072,684,000	1,994,134,000	1,934,521,000	1,994,461,000
Variable cost ($)	28,700,000	28,581,000	28,875,000	28,578,000
Net subsidy for hospitals ($)	4,449,000	4,408,000	4,408,000	4,408,000
Ambulance emergency miles	123,000	125,000	125,000	123,000
Ambulance transfer miles	61,000	50,000	50,000	50,000
Nurses required in area	593	608	608	608
Physician miles	683,000	650,000	650,000	664,000

an inadequacy of the cost estimates or of the decision criterion or both. The first deficiency could be remedied by the use of actual data, the second may potentially be improved by other objective functions. Because the alternative functions provided mixed results, aggressive use of the model as a predictive tool would require careful consideration of the objective function appropriate for one's purposes.

While data on actual physician patient loads are not available for the area, estimates duplicated the findings of Cordes: there was a heavier physician patient load for rural practices than for the nation as a whole. The interaction between services seemed to work quite well, especially the constraint placed on hospital usage by physician availability. While this comparison is rather subjective, in several hospitals where physician availability does restrict hospital usage the model reflected such a restriction. The estimated hospital capacity levels included in the model were lower than actual usage in several instances indicating the actual probability of excess patient demand is higher than the model's assumed probability. For planning, use of effective capacities higher than the usage levels planners consider prudent is illogical, except for comparisons.

As table 1 illustrates, the different objective functions have only minor impacts on the optimal value allowed in the program. Differences occur in usage of certain key hospitals for which market shares are quite sensitive to changes in the way travel is viewed. These hospitals all supply both primary and specialized care, and serve areas with several alternatives for specialized care. In such cases, many factors may determine the choice of hospitals and alternative objective functions including considerations other than travel and cost might be especially appropriate.

Cost minimization explains actual behavior better than other objective functions. This may be because it includes the major characteristics of the other objective functions which are more narrow in perspective. However, these other functions have important normative value, and they reflect possible measures of effectiveness for health planners.

Effect of Changes in the Assumptions

The dependence of linear programming upon its underlying assumptions causes any error in these assumptions to be of special interest. Five changes in assumptions are investigated, two in the method of population prediction, two in demand determination, and one in the cost of patient travel. These are all compared to the minimum cost solution for 1985.

In recent years, major overprediction of the nation's population by demographers occurred because the assumed birth rates were too high (Irwin). Additionally, rural population projections have been off because of inaccurate estimation of off-farm migration. Recognizing the uncertainty associated with these two elements, a test of their importance in health planning is desirable.

As hospital costs increase relative to prices in general, the role of home convalescense may increase. This would result in a reduced stay in the hospital for the same ailment. Improved medical knowledge may increase the speed of recovery causing the same effect. Hence, a reduction in length of hospital stays seems likely and its effect is also investigated.

Increased specialization in health care has dramatically affected the practice of medicine in recent years. Additionally, technical advances have made available a variety of expensive and specialized equipment for those who can afford it. Continuation of this trend toward increased specialization seems likely and the effect of increased specialization is accordingly considered. The possibility of petroleum prices increasing faster than the general price level is discussed frequently. Because petroleum cost is a major cost of travel, a relative increase in travel costs is also considered.

These alternative assumptions were chosen because they either represent a potentially large source of error, in the case of migration assumptions and birth rate changes in population prediction, or because they represent likely changes in the system in future years. The estimated total hospital patient days for the hospitals in the study area under the varying assumptions are shown in table 2.

The effect of changes in population projections stems from changes in the assumptions concerning net-migration and birth rates. Rather than estimating net-migration based on past movements, no net-migration was assumed. This, of course, has different effects for different communities, while an assumption of lower birth rates reduces population in each location by approximately the same amount.

These two changes have quite different effects on the demand for services. In the model

the assumption of no net-migration affected each cohort proportionately, thereby affecting the demand for each service by the same amount, an aggregate increase of 3.9% over the base amounts. The assumption of lower birth rates, on the other hand, affects the size of only the youngest cohort, having no effect on older cohorts. This means that services utilized most heavily by older persons remain relatively unaffected; e.g., ambulance calls fall by only 1.1% while population falls by 6.5%. Emergency room visits, for which only overall usage rates are available, fall by 6.5%. Physician visits, which have relatively equal rates for all population cohorts, fall by 5.6%, while primary and specialized care hospital bed days fall by 1.7% and 1.6%, respectively, reflecting the higher hospitalization rates for older people.

The effect of the assumption of no net-migration on aggregate hospital use in the study area was an increase in patient days from 320,879 to 333,722. Individual hospitals were affected very differently depending upon what the estimated migration for that county had been in the base model. The assumption of lower birth rates, while affecting different hospitals in different ways, had a much more uniform effect, generally a small decrease in usage. In either case the effects on particular facilities can vary, and these changes can have major effects on the optimal size for a new facility. Because hospital construction costs are approximately $65,000 per bed (Hanson, Doeksen, Green) overbuilding by several beds can be a substantial burden on a community.

Increased specialization is accomplished by increasing the specialized care portion of hospital days by 10% for each ailment, the residual being primary care days. This results in an average decrease in primary care days of 3%. While total patient days for hospitals in the study area remain virtually unchanged, the constraints of capacity for some hospitals and the complementarity between physician visits and hospitalization cause the changes to be spread unevenly throughout the system. Also, hospitals supplying both primary and specialized care days are affected differently than other hospitals. These changes are important enough to make consideration of alternative scenarios essential in estimating usage of facilities for health planning purposes.

All hospitals are adversely affected by a 10% stay reduction. Hospitals which were particularly hard hit were those which receive some spillover from nearby hospitals which were operating at full capacity. Stay reduction in these cases decreased patient days by substantially more than 10%.

The final change considered is the effect of increasing travel cost by 100%. Its effect on system behavior is minimal. Total cost increases from $74,321,000 to $74,511,000, a 0.26% rise, and the changes in the solution reduce mileage by only 32,000 miles. The changes are small because local facilities generally have a cost advantage meaning travel is already at a minimum, except where constraints prevent it.

Projecting Future Health Needs

An important task of health planners is estimating future usage of services to better evaluate the need for construction and staffing of proposed facilities. This is a continuing process because existing facilities need replacement and present personnel retire or leave. A major use of the model is projection of the use of the system over some future period. The larger study (Dunn) projected fifteen years of future usage evaluating for this period several investments to alleviate shortages, and several strategies for replacing retiring physicians. Because each instance is unique, specific results are not presented here. Projection of fu-

Table 2. Projected 1985 Utilization of Health Facilities by People of the Study Area under Different Assumptions

	Service Type				
Assumption	Primary Care Days	Specialized Care Days	Ambulance Calls	Physician Visits	Emergency Room Visits
Base model	261,720	73,733	6,695	818,171	35,939
No net migration	271,927	76,609	6,959	850,080	37,341
Lower birth rates	257,474	72,701	6,621	772,353	33,603
Increased specialization	254,347	81,106	6,695	818,171	35,939
Reduced stay	235,548	66,360	6,695	818,171	35,939

with identification of the set of noninferior solutions in decision ($\mathbf{X}^*$) and objective [$z(\mathbf{x}^*)$] space, the shadow prices suggest trade-offs among objectives for each noninferior solution. The array of noninferior decisions with corresponding values of objectives and trade-offs can then be set before the decision maker. Moreover, if $k < 4$, the solutions and trade-offs can be depicted graphically, thereby facilitating the evaluation of alternatives by the decision maker.

Because GP terminates in one decision vector rather than exploring the noninferior set, the results of this procedure do not quantify and make the trade-offs explicit. Thus, the decision maker in a GP paradigm is asked *ex ante* for values of targets (T_i), and perhaps weights (w_i), without knowledge of the range of feasible (let alone noninferior) solutions and is returned a single decision vector (or several if sensitivity analysis is undergone), with insufficient information on alternatives and trade-offs among objectives. Moreover, as Morse (1977, p. 23) suggests, "The duals in GP lose much of their interpretability." His development is quite detailed, but is based on the fact that while in linear programming the objective function coefficients are related to columns (not rows) of the constraint matrix and are independent, in GP the actual decision variables (**x**) have zero objective function coefficients and "the audit trail on the information inherent in the problem's coefficients leads primarily through the RHS of the policy constraints into the objective function" (p. 15). Further, because the policy constraints (14) contain both slack and surplus variables, the optimal basis is degenerate. And the system is driven by a set of weights (w_i) which are not independent.[3]

Quantity of Information

The information supplied is clearly related to the previous criterion. The explicit quantification of trade-offs is possible only if the problem and solution procedure are formulated in a realistic manner which supplies sufficient information for this purpose. The maximum amount of information which can be supplied by the technique is the set of noninferior solutions and the set of all trade-offs among objectives. The weighting and constraint methods provide this maximum quantity of information.

Optimization theory generally involves assessing the relative value of additional increments of the various objectives, given levels of all objectives, rather than assessing their absolute values. Moreover, at any given level of all objectives, it is generally simpler for DMs to evaluate the relative value of trade-offs (marginal increases and decreases) between any pair of objectives than to evaluate their absolute values. Thus, the generating techniques provide sufficient information such that DMs need only assess whether an additional amount of one objective is worth more or less than that which must be sacrificed of another, given the current levels of each. The desire of the DMs, then, would be to find a solution such that they are indifferent between the additional unit of all objectives and their corresponding opportunity costs, given levels of all objectives.

Other techniques, including GP, provide a weaker information set for several reasons. First, because such techniques are designed to reduce the computational requirements and expense by eliciting preference information prior to the problem solution and hence eliminating the search for the complete noninferior set,[4] these approaches provide less information. Second, the quality of the information which is made available by such approaches (which involve obtaining information from the decision makers on subjects about which it is unreasonable to believe they are well informed) is likely to be diminished. This second reason will be expanded upon below. It is sufficient here simply to suggest that more (the maximum) information is supplied by the generating techniques than by goal programming.

Validity of DM-Analyst Interaction

The four criteria used here are fairly awkward and subjective, but probably more useful than some more quantifiable index one might contrive in order to make "less subjective" comparisons. This fourth criterion is defined even

[3] This is true if the weights are chosen as convex combinations (e.g., w_i sum to one). Even otherwise, changing any weight changes all relative relationships among the w_i.

[4] The remaining sets of techniques elicit information from DMs during the solution procedure, but prior to the final solution results. Examples include the Stem method developed by Benayoun et al. and the approach suggested by Candler and Boehlje. An evaluation of several such interactive approaches is provided by Wallenius. In the interest of brevity, these "black box" approaches are not reviewed and compared here.

offs, amount of information supplied, and validity of DM-analyst interaction. It is important to be clear that these comparisons are of generating techniques with GP as it was designed to be, and generally is, used. To be sure, Kornbluth, Brill, and others show how GP could also be used as a generating technique rather than requiring a prior complete specification of G. Indeed, as shown in the appendix the GP formulation (11) through (15) can be made similar to the weighting method (4)–(6) for this purpose. But the present comparison is of methods which require only a partial specification of G with one which, as designed and generally used, requires a complete specification of G. These comparisons suggest that neither approach is superior by all four criteria, so that choice of method will depend on the situation and the analyst's evaluation of the importance of these criteria.

Computational Expense

Because planners typically operate in a world of constrained budgets, computational expense is an important attribute of an adopted decision technique. Candidate measures of computational expense might include dollar costs, computer time, and number of required solutions of a scalarized version of the original problem. Our comparison uses the latter, because the first two are unavoidably problem- and computer-specific.

For the weighting and constraint methods, the number of solutions needed to identify or approximate the noninferior set ($\mathbf{X}^*$) increases with the number of objectives and the chosen level of approximation. Indeed, if N is the number of values of each w_i of (4) used in the weighted method or b_i of (9) in the constraint method, then the number of solutions needed (R) will be an exponential function of the number of objectives (k), namely,

$$R = N^{k-1}. \tag{16}$$

Thus, if one were to apply the constraint method and vary each b_i over six intervals ($N = 6$) for a four objective ($k = 4$) model, then $R = 6^3 = 216$ solutions of the scalarized version would be required. The addition of one more objective would raise the number of required solutions to 1,296.

Goal programming is clearly computationally efficient relative to the generating techniques. Technically, only a single solution of this scalar version of the multiple objective problem needs to be found. However, if solution sensitivity to target levels (T_i) of the k objectives is desired, additional solutions are needed (again, we refer to efforts short of attempting to span the entire noninferior solution space). And if alternate weights (w_i) are to be examined, even more problems need to be solved. Moreover, extensive sensitivity analysis is often required to insure that the GP solutions are noninferior.[2]

In summary, the computational burden of generating techniques is high relative to GP. This is because these methods are based on the incomplete orderings associated with the k objectives, such that alternatives can be dismissed only on the basis of noninferiority. For this reason, the usefulness of techniques such as the weighting and constraint methods is highest for cases in which $k \leq 4$, and diminishes rapidly with increasing numbers of objectives. In addition to the escalation of computer expense and reduced tractability, the appeal of these methods, from the standpoint of offering the decision maker the right kind of information upon which to make choices, disintegrates with the "information overload" brought about by the generating technique solutions with high-dimensioned objective space. Clearly, with $k \geq 4$, the analyst no longer can present the DM with a graphical depiction of $z(\mathbf{x}^*)$. This latter point relates to the other criteria for comparing methods.

Quantification of Trade-Offs

It probably would not be difficult to reach a consensus that for decisions with multiple conflicting objectives, economic analysts can best serve the decision-making process by making clear the trade-offs involved in the alternative choices for the given situation. Certainly, this is a central premise of the work by Marglin (1967), Maass, and many others. Thus, to best serve the public (political) decision-making process, the multiple objective technique should make these trade-offs clear and hence foster (force) the explicit consideration of these opportunity costs.

By this criterion, the weighting and constraint methods are ideally suited to public multiple objective decision making. Along

[2] Cohon and Marks (1975) illustrate this point graphically. It is easily seen that a DM articulating preferences (w_i, T_i) in the absence of knowledge of the noninferior solution space may select levels of T_i, for $w_i > 0$, all of which are feasible and at least one of which can be improved. The GP solution would achieve these levels of T_i and would be inferior.

mathematical programming software packages, with the initial w_i arbitrarily set.

The constraint method is essentially the dual of the weighting approach. It also involves finding noninferior solutions by solving a scalar version of the original multiple objective problem. Because it is relative values of weights that are important, the approach involves selecting the jth objective to maximize subject to the problem constraints plus lower bound constraints on the remaining k-1 objectives. Thus, the original problem becomes

$$(7) \qquad \max z_j(\mathbf{x}),$$

subject to

$$(8) \qquad \mathbf{x} \in \mathbf{X},$$

$$(9) \qquad z_i(\mathbf{x}) \geq b_i, \qquad i \neq j,$$

$$(10) \qquad \mathbf{x} \geq 0,$$

where b_i are the lower bounds on the k-1 objectives. The initial lower bounds can be set by solving the k problems of maximizing (7) subject to (8) and (10), where each j ($j = 1, \ldots, k$) is used in (7) in the k separate solutions, substituting the values of $\mathbf{x}$ for each of the k optimal solutions into $z_i(\mathbf{x})$, and selecting for each $z_i(\mathbf{x})$ lowest of the k values as b_i. The noninferior solution set is then found by solving (7) through (10) with parametric variation of b_i and substitution of each $z_i(\mathbf{x})$, $i \neq j$, into equation (7).

While the weighting and the constraint methods appear similar, the constraint method is generally preferred because it will always solve for the noninferior solution space. By contrast, the weighting method will span the noninferior solution space only under the condition that the objective space is strictly convex. This is demonstrated by Cohon and Marks (1973), who argue that the constraint method also is favored for operational considerations—viz., that parameterization of right-hand sides is more straightforward than parametrically varying weighted coefficients in the objective function.

Among the applications of these techniques are the works of Cohon and Marks (1973), who evaluated the trade-off between net national income and equity of regional income distribution for a developing country; Miller and Byers, who examined the trade-off between environmental quality and income for an agricultural area; and Miller and Erickson. Perlack and Willis and Sinha, Perlack and Willis apply the technique to generate noninferior solutions for a sludge disposal problem for a major metropolitan area. Economic efficiency, environmental impacts, and risk were considered explicitly as objectives in this work. These applications include linear and nonlinear objective functionals and constraints.

Goal Programming

Goal programming is one of the popular techniques, which requires a more complete articulation of preferences prior to solution. Developed by Charnes and Cooper in 1961, it is based upon minimization of the sum of weighted absolute deviations of objectives $[z_i(\mathbf{x})]$ from targets (T_i). Thus, the GP formulation of the initial multiple objective problem is

$$(11) \qquad \min \sum_{i=1}^{k} w_i(d_i + e_i),$$

subject to

$$(12) \qquad \mathbf{x} \in \mathbf{X},$$

$$(13) \qquad \mathbf{x} \geq 0,$$

$$(14) \quad z_i(\mathbf{x}) - d_i + e_i = T_i, i = 1, \ldots, k, \text{ and}$$

$$(15) \qquad d_i, e_i \geq 0,$$

where d_i and e_i are the positive and negative differences of the ith objective from its target, respectively, and w_i is the weight or priority attached to the ith goal. The w_i can also be split into two components—one for positive differences (d_i) and one for negative differences (e_i). Neely, North, and Fortson provide an example.

In addition to the Neely, North, and Fortson work mentioned earlier, examples of GP applications include: a similar application by North, Neely, and Carlton (1977); Charnes, Cooper, and Ferguson, who apply the technique to executive compensation levels; Harald et al., who use GP to evaluate managerial standards for a program of marine environmental protection; Sfeir-Younis and Bromley, who evaluate public investments in LDCs; and Lee, who reports applications in the areas of finance, marketing, school bussing, accounting, and a number of others. The survey of GP by Kornbluth also provides useful background in this area.

Comparison of Methods

Recall that the criteria for evaluation are computational expense, quantification of trade-

plicit quantification of tradeoffs, quantity of information supplied, and validity of DM-analyst interaction.

The next section describes the vector optimization concept and a portion of the available multiple objective decision-making techniques, featuring the generating class and goal programming. These descriptions can be supplemented by reference to the excellent survey by Cohon and Marks (1975) and to Bishop et al., among others. The subsequent section contrasts the generating and GP techniques according to the four criteria indicated above. A final section summarizes the points made and offers some parting observations.

Vector Optimization

The problem of multiple objective decision making generally can be described as

$$(1) \quad \max z(\mathbf{x}) = G[z_1(\mathbf{x}), z_2(\mathbf{x}), \ldots, z_k(\mathbf{x})],$$

subject to

$$(2) \quad \mathbf{x} \in \mathbf{X}, \text{ and}$$

$$(3) \quad \mathbf{x} \geq 0,$$

where $z(\mathbf{x})$ is the k-dimensional objective function (there are k objectives); $\mathbf{x}$ is an n-dimensional vector of decision variables; (2) is the set of m constraints for the problem; and (3) is the set of nonnegativity conditions. Equations (2) and (3) define the feasible region in n-dimensional Euclidean space. Each feasible solution to the problem implies a value for each objective $[z_i(\mathbf{x}), i = 1, \ldots, k]$. The k-dimensional objective function (1) maps the feasible region in decision space ($\mathbf{X}$) onto the feasible region in objective space $z(\mathbf{X})$, which is defined in k-dimensional Euclidean space.

With the operator G completely unspecified, it would be impossible to order the objectives, and the vector (1) cannot be optimized. Without information about preferences with which to combine objectives, the objectives are incommensurable and solutions cannot be compared.

However, even in the absence of complete value judgments about the k objectives, a portion of the feasible solutions can be dismissed on the basis of a partial ordering. With the assumption that more of each objective is preferred to less, only the noninferior solutions are relevant. A noninferior solution is a feasible solution to the problem, $\mathbf{x} \in \mathbf{X}$, such that no other feasible solution, $\bar{\mathbf{x}} \in \mathbf{X}$, exists for which $z_p(\bar{\mathbf{x}}) > z_p(\mathbf{x})$ for some $p = 1, 2, \ldots, k$, and $z_i(\bar{\mathbf{x}}) \geq z_i(\mathbf{x})$ for all $i \neq p$. Noninferior solutions can be defined in decision space ($\mathbf{X}^*$) as well as in objective space $[z(\mathbf{x}^*)]$, because each noninferior solution $\mathbf{x} \in \mathbf{X}^*$ implies a value for each of the k objectives $z(\mathbf{x})$. The techniques described below are methods of generating or solving for the set of noninferior solutions to the problems (1)–(3), where the operator G is specified such as a partial ordering. Noninferior solutions are preferred to inferior ones, and any further ordering of noninferior solutions is done by the DM after receiving the model results.

Generating Techniques

The primary approaches included in the class of generating techniques derive directly from the Kuhn-Tucker conditions for noninferior solutions (Cohon and Marks 1975, Brill, Bishop et al., Roy, and Wallenius). These techniques were developed with the objective of identifying $\mathbf{X}^*$ and $z(\mathbf{X}^*)$. Without preferences (value judgments), these techniques provide all the information which can be derived from a multiple objective model.

The weighting and constraint methods[1] are the most common of the generating techniques, both following from Kuhn and Tucker. The weighting method involves solving for noninferior solutions by converting the original problem defined by (1)–(3) to a scalar optimization problem, in which the objective function becomes a weighted sum of the arguments of (1). That is,

$$(4) \quad \max \sum_{i=1}^{k} w_i \, z_i(\mathbf{x}),$$

subject to

$$(5) \quad \mathbf{x} \in \mathbf{X},$$

$$(6) \quad \mathbf{x} \geq 0,$$

where $w_i \geq 0$ for all i and strictly positive for at least one. Thus $\mathbf{X}^*$ and $z(\mathbf{X}^*)$ can be generated by parametric variation of w_i with existing

[1] The rudiments of the weighting and constraint methods are found in the works of McKean, Marglin (1962), Eckstein, and Freeman. Their intent was not to generate the entire noninferior set, but rather to identify an optimal set of weights and then proceed directly to the social optimum. Candler and Boehlje do likewise in an interactive mode.

A Comparison of Generating Techniques and Goal Programming for Public Investment, Multiple Objective Decision Making

C. E. Willis and R. D. Perlack

The move toward public decision making based on multiple objective analysis has occurred largely during the past decade. During this brief interval dozens of techniques have been advanced for this purpose. The class of (generating) techniques which do not require prior articulation of preferences and which provide alternative solutions rather than a single optimum is characterized and compared to goal programming. Goal programming, as generally employed, seeks a single optimum solution given an articulated set of targets and priorities on the relevant objectives. Four criteria were used in this comparison and neither approach was found to be unambiguously superior.

Key words: generating techniques, goal programming, multiple objective decision making.

The ongoing transformation in many public policy areas from decision making based upon traditional planning models featuring a single objective to multiple objective analysis has promoted a field of mathematical programming called vector optimization. This field is not new, having been created in 1951 by Koopmans and by Kuhn and Tucker. It has been only in the past decade, and particularly during the latter portion of it, that serious effort has been given to developing solution techniques for these types of problems. During this relatively brief interval, more than two dozen different techniques for solving multiple objective programming problems have been advanced. Many of these are confined to the generation of the set of noninferior solutions to the problem, and do not require an articulation of preferences among goals by the decision maker (DM). The remaining techniques do require a prior, or a sequential, articulation of preferences, with the result being a single optimum solution rather than a set of noninferior solutions.

With some notable exceptions, agricultural economists have lagged a bit behind other operations researchers and management scientists in adopting these techniques. Most exceptions have involved the use of goal programming (GP) or lexicographic programming (a form of GP with preemptive weights), which require an articulation of preferences. Neely, North, and Fortson provide a recent illustration of the use of GP for multiple objective decision making for public water resources projects.

The present purpose is to characterize the class of multiple objective (generating) techniques which do not require a prior articulation of preferences and which provide alternative solutions rather than a single optimum decision, to characterize the GP approach as one technique within the class of approaches which provide an optimum solution given an articulated set of targets and priorities on the relevant objectives, and to evaluate the strengths and weaknesses of these two approaches. Ultimately, the choice among these available approaches for any given problem itself involves comparison relative to multiple objectives, e.g., computational expense, ex-

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ture use is where the mixed integer capabilities become important, because investment is a major consideration in future planning.

This paper describes a health systems model which allows analysis of multiple services and includes spatial and monetary considerations. The model and its validation are discussed and empirical results are presented for a health systems area in northwestern Oklahoma. Several objective functions were minimized, each behaviorally reasonable while reflecting possible goals of the health planning decision makers, and the differences resulting from these alternative objective functions are examined.

Also several assumptions regarding future changes were tested and the impact of these changes were examined. Where information for empirical validation is available it is utilized, but in general validation is of the rational variety. The empirical validation conducted showed the model to be strongest in the very rural areas and weakest within the commuting areas of cities. The solution was quite sensitive to changes in migration and treatment practices and quite insensitive to changes in birth rates and travel costs. The values of the different objective functions changed little under the alternative objective functions. However, changes in the assumptions affecting the aggregate level of demand caused changes in the objective functions of considerable magnitude. The alternative objective functions mainly caused shifting between specialized service centers. The estimation of future usage and the evaluation of the feasibility of a facility replacement or expansion decision is the potentially most valuable use of the model to the health planner. This value is enhanced by the models' use of data which health planners have at their disposal and ought to include in the decision process anyway.

References

American Medical Association. *AMA Profile of Medical Practice*. Chicago, 1974.

Berki, Sylvester E. *Hospital Economics*. Lexington, Mass.: Lexington Books, 1972.

Cordes, Sam M. "Comparative Productivity among Different Sized Physician Practices in Rural Washington." *Northeastern Agr. Econ. Council J.* 2(1973):153–61.

Daberkow, S. G., and G. A. King. "Response Time and the Location of Emergency Medical Facilities in Rural Areas: A Case Study." *Amer. J. Agr. Econ.* 59(1977):467–77.

Doeksen, Gerald A., Jack Frye, and Bernal Green. *Economics of Rural Ambulance Service in the Great Plains*. USDA ERS Agr. Econ. Rep. No. 308, Nov. 1975.

Duncan, Marvin R., and Earl O. Heady. "A Programming Model for Analysis of Non-Metropolitan Hospital Services Systems and Application of the Model." CARD Rep. 64, Center for Agricultural and Rural Development, Iowa State University, Feb. 1976.

Dunn, James W. "A Mathematical Model for Analysis of Rural Health Care Systems." Ph.D. thesis, Oklahoma State University, 1977.

Feldstein, Martin S. *Economic Analysis for Health Service Efficiency*. Amsterdam: North-Holland Publishing Co., 1967.

Hanson, Ivan, Gerald A. Doeksen, and Bernal L. Green. "Capital and Operating Costs of Rural Hospitals." Manuscript in process.

Irwin, Richard. *Guide for Local Area Population Projections*. Washington, D.C.: U.S. Department of Commerce, Bureau of the Census Tech. Pap. 39, July 1977.

Joseph, Hyman. "Empirical Research on the Demand for Health Care." *Inquiry* 8(1971):67–71.

Lubin, Jerome W., Irene M. Reed, Gordon L. Worstell, and Daniel L. Drosness. "How Distance Affects Physician Activity." *Modern Hospital* no. 1 (1966), pp. 80–82.

May, Alan, Gerald A. Doeksen, and Bernal L. Green. *Utilization of Health Services in the Great Plains*. Washington, D.C.: USDA ESCS Agr. Info. Bull. No. 414, Mar. 1978.

National Center for Health Statistics. *Eighth Revision International Classification of Diseases, Adapted for Use in the United States*. Washington, D.C.: U.S. Public Health Service Pub. No. 1693, 1967.

Naylor, Thomas H. *Computer Simulation Experiments of Economic Systems*. New York: John Wiley & Sons, 1971.

Oklahoma Health Planning Commission. *Hospital Utilization Report, 1976*. Oklahoma City, Okla. 1976.

Oklahoma State Health Planning Agency. *Patient Origin Study: A Report Identifying the Movement of Oklahoma Residents Seeking Hospital Services*. Oklahoma City, Okla. 1973.

Schonfeld, Frank, Jean F. Heston, and Isidore S. Falk. *Standards for Good Medical Care: Based on the Opinions of Clinicians Associated with the Yale-New Haven Medical Center with Respect to 242 Diseases*, 4 vol. Washington, D.C.: U.S. Department of Commerce, Nat. Tech. Info. Ser. Pub. No. PB-240, 385–88, 1975.

Smallwood, R. D., E. J. Sondik, and F. L. Offensend. "Towards an Integrated Methodology for the Analysis of Health Care Systems." *Operations Res.* 19(1971):1300–22.

Van Wagner, Karen. Assistant Director of Planning, Oklahoma Health Systems Agency. Personal interview, 22 Oct. 1976.

more loosely than the others. However, it is hoped that the discussion below will enable the formation of judgments on the conditions under which generating techniques or goal-programming procedures are favored according to this criterion. The treatment begins with GP and the difficulty of setting weights and targets and leads naturally to a discussion of human choice theory and its implications for the possibility of the setting of such weights as well as of evaluating the results of the generating technique. Next, the implications of naively setting such values are suggested. Finally, the generating techniques are considered as a means for facilitating the search for the preference structure of the decision maker.

The GP approach can be an extremely useful tool for situations in which the DM often commands the system in question (e.g., many private sector decisions) and where the DM generally has a clearer notion of targets and priorities. It is less so for situations frequently characterized by a relatively complicated system or process of decision making in which no individual is capable of setting targets. Public projects, for example, are seldom developed with specific targets of the objectives in mind; that it is generally relative, rather than absolute, levels of objectives which are of primary importance.

Furthermore, for the GP the DMs are expected to quantify targets and weights without the information on trade-offs contained in the noninferior set and are presumed to be in possession of a multiattribute utility function which is separable, additive, and stable over decision iterations. Not only is this a restrictive specification of the utility function, it is unlikely that this preference structure is completely known by the DM. In combination with the results of a great deal of research in psychology indicating a rather limited information processing capacity of the human brain, this suggests that the DM may have great difficulty in articulating weights (w_i) associated with the various objectives. Morse (1976) provides a useful summary of the human choice theory literature, featuring such main works as Thurstone, Luce, Coombs, Tversky, and Keeney and Raiffa.

In brief, the literature suggests that choosing is difficult, that large amounts of data aggregate poorly and are associated with trade-offs (weights) that are unstable over time, and that they are not representable by separable additive utility functions. As Zeleny argues, these weights are not a priori in the possession of the DM. Rather, they are, or should be, learned through the decision process and are not independent of the set of feasible alternatives.

Given these difficulties with assigning weights to objectives on the part of a DM, what are the implications of "second best" assignments of weights? The practice of placing highest weights on the most important objectives, and vice versa, results in what Morse (1977) terms "naive weights." As it turns out, it is very hard to predict how these weights will drive even a linear system in a GP context. Indeed, Morse devised numerical examples which showed little correspondence between priority weights and goal attainment. Increasing a priority weight on objective i may lead in fact to a lower attainment of the ith goal.

Sensitivity analysis is complicated in goal programming in part because the actual decision variables have zero coefficients in the objective function; and this information makes its way into the objective function only indirectly through the right-hand side (T_i) of the policy constraints (Morse). These goal constraints (14) have both surplus (d_i) and slack (e_i) variables, and these variables are driven by a set of dependent objective function coefficients, so that for one to change at least one other must change as well. This is because weights are usually set to insure convex combinations by making them sum to one. Even without this restriction, adjusting a single weight alters the relative relations of the w_i.

Of course, the same set of findings of information processing limitations in humans which makes it difficult to set weights and targets a priori also makes it difficult to make a final decision when confronted with the great volume of information supplied by generating techniques. Clearly, the case can be made that the vast quantities of information associated with a problem of many objectives may so baffle the DM, that the decision based on a GP approach with naively set weights and targets may be as sensible as, or more so than, a decision resulting from the information overload of a generating technique. In this regard, pruning procedures (automated elimination of a subset of solutions) may be of value (see Morse 1977).

If the "overload" problem is not too severe, the DMs in a generating technique context are

aided in their search for the preference structure by being supplied pairs of noninferior feasible alternatives, the objective values, and trade-offs and being asked to compare these solution pairs (Coombs). The generating technique, in contrast to the GP structure, offers an intuitive approach to the problem. It leaves to the computer what it does best (generating alternatives) and to the DMs what they do best (evaluating pairs).

Summary

While multiple objective decision-making approaches are not new, they have only recently begun to be used operationally. In the agricultural economics applications, variations of goal programming or lexicographic programming seem to predominate. Neely, North and Fortson provide a good example of the use of goal programming in a recent issue of this *Journal*.

Goal programming succeeds in reducing computational requirements by requiring of DMs value judgment on targets for each goal (absolutes, not relatives) as well as weights on deviations from these targets. This is done without the benefit of knowledge of the feasible alternatives and trade-offs. Several studies in psychology show the difficulty of setting weights on deviations from targets (knowing one's preference structure), and indeed it was noted that GP weight setting implies a very restrictive form of utility function. Given this limitation, recourse to naive weights often follows. Morse's 1977 work shows that if naive weights are used, the system may be driven in counter-intuitive and inferior ways.

Goal programming is clearly superior to generating techniques on the basis of computational ease and expense—indeed, as the number of objectives increases beyond, say, four, the computations required in the generating techniques become extreme. However, the generating techniques fared relatively better by the other three criteria: trade-offs were explicit, maximum amount of information was provided, and the interaction between DM and analyst was on a logical and sound basis.

In short, multiple objective methods likely will grow in importance in empirical applications. Generating techniques may become the most important of these approaches because of their intuitive basis, the explicit quantification of trade-offs they supply, and the assistance to the learning process they provide. Goal programming may prove more useful for situations characterized by many objectives, and cases in which the DM has a good handle on target levels, weights on deviations, and the system in question (and this knowledge is much more likely to be held in private than in public sector problems).

Finally, it merits restating that in the interest of length, the interactive multiple objective procedures have not been discussed here. These approaches can prove valuable in many decision settings and can be combined with basically generating-type techniques, as in Candler and Boehlje, as well as with GP applications, as in Monarchi, Weber and Duckstein. Wallenius provides a summary and comparison of interactive techniques.

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References

Benayoun, R., J. De Montgolfier, J. Tergny, and O. Laritchen. "Linear Programming with Multiple Objective Functions: Step Method (Stem)." *Math. Program.* 1(1971):366–75.

Bishop, A. B., M. McKee, T. W. Morgan, and R. Narayanan. "Multiobjective Planning: Concepts and Methods." *J. Water Resour. Plan. and Manage. Div. ASCE* 102(1976):239–53.

Brill, E. Downey, Jr. "The Use of Optimization Models When We Don't Know What to Optimize." Presented at the Joint National Meeting of ORSA/TIMS, Altanta, Ga., 9 Nov. 1977.

Candler, Wilfred, and Michael Boehlje. "Use of Linear Programming in Capital Budgeting with Multiple Goals." *Amer. J. Agr. Econ.* 53(1971):325–30.

Charnes, A., and W. W. Cooper. *Management Models and Industrial Applications of Linear Programming*, vol. 1. New York: John Wiley & Sons, 1961.

Charnes, A., W. W. Cooper, and R. Ferguson. "Optimal Estimation of Executive Compensation by Linear Programming." *Manage. Sci.* 1(1955):138–51.

Cohon, J. F., and D. H. Marks. "Multiobjective Screening Models and Water Resource Investment." *Water Resour. Res.* 9(1973):826–36.

Cohon, Jared L., and David H. Marks. "A Review and Evaluation of Multiobjective Programming Techniques." *Water Resour. Res.* 11(1975):208–20.

Coombs, Clyde. *A Theory of Data.* New York: John Wiley & Sons, 1964.

Eckstein, Otto. "A Survey of Public Expenditure Criteria." *Public Finance: Needs, Sources, and Utilization.* Princeton, N.J.: Princeton University Press, 1961.

Freeman, A. Myrick. "Project Design and Evaluation with Multiple Objectives." *Public Expenditures and Policy Analysis*, ed. R. Haveman and J. Margolis. Chicago: Markham, 1970.

Gembicki, F. "Vector Optimization for Control with Performance and Parameter Sensitivity Indices." Ph.D. thesis, Case Western Reserve University, 1973.

Haimes, Y. Y., W. A. Hall, and H. T. Freedman. *Multiobjective Optimization in Water Resources Systems*. New York: Elsevier, 1975.

Harrald, Jack, Joseph Loetta, Ernest Loo, William A. Wallace, and Richard Wendell. "The Use of Goal Programming in Evaluating Managerial Standards for a Marine Environmental Protection Program." Washington, D.C.: U.S. Coast Guard Headquarters, Marine Environ. Protect. Prog. Work. Pap., 1975.

Keeney, Ralph L., and Howard Raiffa. *Decisions with Multiple Objectives: Preferences and Value Tradeoffs*. New York: John Wiley & Sons, 1976.

Koopmans, T. C. "Analysis of Production as an Efficient Combination of Activities." *Activity Analysis of Production and Allocation*, ed. T. C. Koopmans, Cowles Commission Mono. 13, pp. 33–97. New York: John Wiley & Sons, 1951.

Kornbluth, J. "A Survey of Goal Programming." *Omega* 1(1973):193–205.

Kuhn, H. W., and A. W. Tucker. "Nonlinear Programming." *Proceedings of the Second Berkeley Symposium on Mathematical Statistics and Probability*, ed. J. Neyman, pp. 481–92. Berkeley: University of California Press, 1951.

Lee, Sang M. *Goal Programming for Decision Analysis*. Philadelphia, Pa.: Auerbach, 1972.

Luce, R. Duncan. *Individual Choice Behavior: A Theoretical Analysis*. New York: John Wiley & Sons, 1964.

Maass, A. "Benefit-Cost Analysis: Its Relevance to Public Investment Decisions." *Water Research*, ed. A. V. Kneese and S. C. Smith. Baltimore, Md.: Johns Hopkins University Press, 1966.

Marglin, Stephen A. "Objectives of Water-Resource Development: A General Statement." *Design of Water Resource Systems*, ed. A. Maass, M. Hufschmidt, R. Dorfman, H. Thomas, Jr., S. Marglin, and G. Fair. Cambridge, Mass.: Harvard University Press, 1962.

———. *Public Investment Criteria*. Cambridge, Mass.: MIT Press, 1967.

McKean, Roland N. *Efficiency in Government Through Systems Analysis*. New York: John Wiley & Sons, 1958.

Miller, W. L., and D. M. Byers. "Development and Display of Multiple Objective Impacts." *Water Resour. Res*. 9(1973):11–20.

Miller, W. L., and S. P. Erickson. "The Impact of High Interest Rates on Optimum Multiple Objective Design of Surface Runoff Urban Drainage Systems." *Water Resour. Bull.* 11(1975):49–59.

Monarchi, D. E., J. F. Weber, and L. Duckstein. "An Interactive Multiple Objective Decision-Making Aid Using Non-Linear Goal Programming." *Multiple Criteria Decision-Making*, ed. M. Zeleny. New York: Springer-Verlag, 1976.

Morse, J. N. "Human Choice Theory: Implications for Multicriteria Optimization." Paper presented at TIMS/ORSA National Meeting, Miami, Fla., 9 Nov. 1976.

Morse, J. N. "A Theory of Naive Weights." Paper presented at the Conference on Multiple Criteria Decision-Making, Buffalo, N.Y., 21–26 Aug. 1977.

Neely, Walter P., Ronald M. North, and James E. Fortson. "An Operational Approach to Multiple Objective Decision-Making for Public Water Resources Projects Using Integer Goal Programming." *Amer. J. Agr. Econ.* 59(1977):198–203.

North, R. M., W. P. Neely, and R. L. Carlton. "Balancing Economic and Environmental Objectives." *Transactions of the North American Wildlife and Natural Resources Conference*, 190–202, 1977.

Perlack, Robert D., and Cleve E. Willis. "Land Application of Sewage Sludge: An Application of Multiple Objective Methods." Paper presented at the annual meeting of the AAEA, Blacksburg, Va., 6–9 Aug. 1978.

Roy, B. "Problems and Methods with Multiple Objective Functions." *Math. Program.* 1(1971):239–66.

Sfeir-Younis, Alfredo, and D. W. Bromley. "Multiobjective Formulation and Evaluation of Public Investments in LCDs: A Goal Programming Approach." Paper presented at the AAEA meetings, Blacksburg, Va., 6–9 Aug. 1978.

Sinha, Prabhakant, Robert D. Perlack, and Cleve E. Willis. "A Multiple Objective Knapsack Problem Approach to Sewage Sludge Disposal Alternatives." Paper presented to ORSA/TIMS meetings, Los Angeles, 7–9 Nov. 1978.

Thurstone, L. L. "A Law of Comparative Judgment." *Psych. Rev.* 34(1927):273–86.

Tversky, Amos. "Choice by Elimination." *J. Math. Psych.* 9(1972):341–67.

Wallenius, J. "Comparative Evaluation of Some Interactive Approaches to Multicriterion Optimization." *Manage. Sci.* 21(1975):1387–96.

Zeleny, Milan. *Linear Multiobjective Programming*. Lecture Notes in Economics and Mathematical Systems, No. 95. New York: Springer-Verlag, 1974.

Appendix

GP as a Generating Technique

The comparisons made earlier were of generating techniques with GP as it is generally used (*viz.*, as a technique which uses a previously articulated set of preferences). Haimes, Hall, and Freedman (p. 25) indicate that, "just as in the parametric case, the noninferior set can be generated by varying the weighting factors, but it can be shown that this method suffers from the same duality gap problem as the parametric approach when the problems are nonconvex." The "parametric case" to which they refer is what we have called the weighting method. The presence of this duality gap (an inability to generate all noninferior solutions in the nonconvex case) has been proven

by Gembicki. It is shown below that if the purpose of the analyst is to investigate the noninferior solution space, GP can be used in the same way as the weighting method. In fact, arguments made previously suggest that for this purpose, the constraint method is generally more practical.

To show that GP is equivalent to the weighting method, rewrite (14) as

$$-d_i + e_i = T_i - z_i(\mathbf{x}), \tag{17}$$

and substitute (17) into (11), producing

$$\min \sum_{i=1}^{k} w_i[T_i - z_i(\mathbf{x})], \text{ or} \tag{18}$$

$$\min \left[\sum_{i=1}^{k} w_i T_i - \sum_{i=1}^{k} w_i z_i(\mathbf{x}) \right]. \tag{18$'$}$$

Because $\sum_{i=1}^{k} w_i T_i$ is a constant, minimization of (18)′ is equivalent to minimization of $\sum_{i=1}^{k} w_i[-z_i(\mathbf{x})]$. Thus, the GP problem can be expressed as

$$\max \sum_{i=1}^{k} w_i[z_i(\mathbf{x})], \tag{19}$$

subject to (12)–(15), which is precisely the weighting method model (4)–(6) with the constraints (14) and (15) added.

Measuring the Indirect Effects of an Agricultural Investment Project on Its Surrounding Region

C. L. G. Bell and P. B. R. Hazell

Agricultural investment projects may generate important downstream benefits for the regions in which they are located. Using a semi-input-output model of the regional economy, an attempt is made to quantify the downstream benefits generated by an irrigation project in Malaysia. In aggregate the project's downstream effects on regional income were of an order similar to its direct effects, but the main beneficiaries of the downstream benefits were the nonfarm households. Each dollar of downstream income probably was supported by just over a dollar of additional investment in the local economy.

Key words: growth linkages, input-output analysis, Malaysia, project appraisal, regional development.

Investment projects may generate substantial indirect effects, or pecuniary external economies, as Scitovsky would call them. These effects stem partly from production linkages. First, the project will generate demands for investment and intermediate goods. Second, the rise in output due to the project may cheapen supplies to other sectors, and so increase the profitability of new investment in those sectors, a case which has been analyzed extensively by Chenery. But consumption linkages also come into play if the extra income flowing from the project boosts the level of final demand in the economy. Hirschman, in arguing for the relative neglect of agriculture in development strategies, discounted the value of these linkages for agricultural investments. Recently, however, both Mellor and Johnston and Kilby have renewed debate on the importance of these linkages for economic growth in developing countries, with Mellor laying particular stress on the importance of final linkages arising from increases in agricultural incomes.

It is also of interest to ascertain how the indirect (or "downstream") effects of a project affect the distribution of incomes. For example, while an agricultural project may generate a strong rise in the incomes of all farm households, the resulting downstream benefits may be reaped by richer nonfarm households. There is also a regional dimension to this issue. Suppose an agricultural project produces powerful downstream effects upon its surrounding region, which was previously poor. Then, as Mellor has emphasized, income disparities among agricultural regions will be increased all the more, even though the income gap between industrial regions and that receiving the project will narrow.

Another consideration is that knowledge about the structural sources of downstream effects could be useful in improving the design of integrated regional development strategies. In particular, if the structure and relative strength of linkages are known, then public policy can attempt to see that such linkages function without friction.

In this paper we propose and apply an approach to measuring the magnitude and incidence of regional downstream effects, based on a social accounts matrix (Pyatt et al.) and a variant of Tinbergen's semi-input-output method. We begin by sketching the main features of the Muda River project and surrounding region in northwestern Malaysia, the sub-

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ject of our empirical application. Next, we discuss the considerations influencing our choice of methodology and then present the semi-input-output model on which the quantitative analysis is based. Subsequently, we use this model to estimate the direct and indirect effects of the project at maturity (in 1974) on output and incomes in the regional economy. In so doing, we also estimate both the pace and pattern of the region's growth over the period 1967–74 and those which would have occurred in the hypothetical event that the project had not been undertaken. Finally, we provide some sketchy estimates of all the balancing investments needed to support the downstream incomes generated by the project.

The Project and Its Region

The project involved a total investment over the period 1967–73 of about $270 million in the form of dams, a canal system, feeder roads, and drainage infrastructure for the irrigation of 240,000 acres of paddy land.[1] Before irrigation, a single paddy crop was grown each year in harmony with the rainfall pattern. Double cropping followed irrigation, and the accompanying introduction of quicker maturing, fertilizer-responsive varieties also has increased yields. The incomes of the 51,000 farm households in the project's command area almost doubled over the period 1967–74, and the region claimed new prominence as the supplier of some 40% of Malaysia's annual rice requirements. Nevertheless, the region is still relatively poor, with a per capita gross domestic product in 1972 of $600 compared to $1100 for Malaysia as a whole.

The basis for the spatial definition of the regional economy is discussed in a United Nations FAO/IBRD Report (pp. 22–24). In brief, the region encompasses the whole of the state of Perlis and about half of Kedah. It comprises the irrigation command area, a further 70,000 acres of low-lying, rain-fed paddy land, and a fringe area made up mostly of rubber smallholdings. The region's population was 687,100 in 1972, 16% of whom were resident in towns with 5,000 people or more, and 81% lived within the boundaries of the irrigation command area.

We have distinguished between five household classes to reflect the income distribution aspects of regional activities. Our definitions rest on socioeconomic criteria: in particular, endowments of labor and land, access to irrigation, and sector of employment. The three agricultural household classes within the project area are: (*a*) "landless" households, which derive most of their income from employment on other paddy farms; (*b*) "labor abundant" farm households, which possess a high ratio of family labor to area operated; and (*c*) "land abundant" households, which hire in substantial amounts of nonfamily labor. Clearly, the household's endowments of land and labor are connected intimately with its labor market transactions, which underlie the definitions adopted here.

Farm households outside the project area are engaged heavily in "other agriculture" as well as the production of rubber and/or unirrigated main season paddy. They also supply labor to households in the project area at the times of peak activity in paddy cultivation. As their economic activities are different from those of farm households within the project area, and there is an intrinsic interest in what happens to households outside, but on the periphery of, large development projects, they merit the status of a separate household category.

Nonfarm households account for 35% of the region's population, and they display wide variations in income and wealth. Ideally, therefore, they should be subdivided into further categories. However, data to place them in more refined classes were lacking. A majority of nonagricultural households are ethnic Chinese, who generally enjoy higher per capita incomes than the predominantly rural Malays. A summary picture of population and incomes for these classes in 1972 is set out in table 1.

The region's production structure was disaggregated into the thirty-five sectors listed in table 3. These definitions are generally straightforward. Cases arose where two or more sectors produced the same commodity. This happened because either the commodity was produced under different institutional arrangements with important differences in technology and/or in the distribution of sectoral value added among households, e.g., small and commercial rice mills, or because the commodity took different forms according to its end use or type of demand it could sat-

[1] All monetary values are in 1972 Malaysian dollars unless otherwise indicated.

Table 1. Socioeconomic Characteristics of Household Classes in 1972

	Landless Paddy Workers	Labor-Abundant Paddy Farms	Land-Abundant Paddy Farms	Other Agricultural Households	Nonfarm Households	All Households
Number of households	4,367	18,045	33,426	25,333	44,047	125,239
Number of persons (thou.)	21.3	103.3	184.7	131.8	246.0	687.1
Average family size	4.88	5.72	5.53	5.20	5.58	5.49
Income per family ($)	1,029	1,568	2,528	1,825	4,984	3,059
Income per capita ($)	211	274	457	351	893	557

Source: Bell et al.

isfy, e.g., road and rail transport, residential and nonresidential construction.

Methodological Considerations

Two considerations bore heavily on our choice of methodology. First, to capture adequately the effects flowing from interindustry and final demand linkages between agriculture and the rest of the economy, some degree of sectoral disaggregation may be necessary. Also, the evidence on household expenditure and savings behavior suggests the need to disaggregate households by income levels. These considerations can be accounted for at any point in time through the construction of a social accounting matrix (SAM). In the present case, sufficient data were at hand to construct a detailed regional SAM for 1972 (Bell et al.)

Second, because a project's implementation is almost invariably accompanied by changes in the levels of regional activities which owe nothing to the advent of the project, e.g., technical change, autonomous private investment, and government spending, a correct analysis of its impact at maturity requires construction of a "picture" of how the economy would have looked in the absence of the project. Pictures of the economy may also have to be constructed for the pre- and/or post-project situations if sufficient primary data are not available for the estimation of SAMs for the years in question. In constructing these pictures, the most important assumptions concern the choice of exogenous variables. For each sector one must decide whether output or final demand is to be fixed exogenously. This led us to a variant of the semi-input-output method, which can accommodate a choice between inelastically fixed supply and inelastically fixed demand in each sector—unlike the standard formulation of the closed Leontief system, in which the complete bill of gross outputs follows solely from the set of final demands.

A Semi-Input-Output Model

Beginning with the set of material balances, we have

$$(1)\qquad X_i = \sum_{j=1}^{n} a_{ij}X_j + \sum_{k=1}^{h} C_{ik} + J_i + E_i,$$

there being n commodities (sectors) and h types of household; X_i denotes the gross output of sector i, a_{ij} the input of commodity i needed to produce a unit of commodity j, C_{ik} the expenditure of household class k on commodity i, J_i the deliveries of good i to investment activities, and E_i the net exports of good i.

The gross income of each household class is made up of direct earnings in commodity production and distributed profits from incorporated enterprises plus net transfers (R^*_k) from other household classes and abroad. The first two are taken to be proportional to gross output, whereas the latter are assumed to be exogenous. Choosing physical units of measure such that all commodity prices are unity, we have

$$(2)\qquad Y_k = \sum_j \omega_{kj}X_j + R^*_k.$$

The claims on such incomes are taxes, savings, and consumption expenditures. The tax schedule is assumed to be linear in income

$$(3)\qquad T_k = t_kY_k + T^*_k.$$

Savings are assumed to be proportional to disposable incomes,

$$(4)\qquad S_k = s_k(Y_k - T_k),$$

as there were no data to warrant a more com-

plicated form. Finally, household class k's expenditure on good i is assumed to be a linear function of its total outlays on consumption,

$$C_{ik} = \gamma_{ik} + \beta_{ik}C_k. \tag{5}$$

Here we must enter a qualification concerning household's purchases of the outputs produced by government sectors. Households may make small cash outlays on some services, such as education and health, but their overall consumption of government services depends on the size of (exogenous) government expenditures and administrative "access" rather than disposable income. Hence, the relevant C_{ik} are fixed in relation to the corresponding gross output levels quite independently of the household's income-outlay identity: $Y_k \equiv T_k + S_k + C_k$. However, to preserve the latter, the actual cash outlays on government education and health must then be treated as taxes, the relevant γ_{ik} and β_{ik} being absorbed into T^*_k and t_k, respectively.

Substituting (3), (4), and (5) into (1), and combining the result with (2), we obtain the following more compact system:

$$\left[\begin{array}{c|c} I - A & -Bc \\ \hline -\Omega & I \end{array}\right]\left[\begin{array}{c} \mathbf{X} \\ \hline \mathbf{Y} \end{array}\right] = \left[\begin{array}{c} \Gamma\mathbf{u} \\ \hline \mathbf{0} \end{array}\right] - \left[\begin{array}{c} B(I - s)\mathbf{T}^* \\ \hline \mathbf{R}^* \end{array}\right] + \left[\begin{array}{c} \mathbf{J} \\ \hline \mathbf{0} \end{array}\right] + \left[\begin{array}{c} \mathbf{E} \\ \hline \mathbf{0} \end{array}\right], \tag{6}$$

where A denotes the $n \times n$ matrix (a_{ij}); B, the $n \times h$ matrix (β_{ik}); c, the $h \times h$ diagonal matrix whose elements are $c_k = (1 - s_k)(1 - t_k)$; Γ, the $n \times h$ matrix (γ_{ik}); $\mathbf{E}$, the $n \times 1$ vector (E_i); $\mathbf{u}$, an $h \times 1$ vector of ones; $\mathbf{J}$, the $n \times 1$ vector (J_i); $\mathbf{R}^*$, the $h \times 1$ vector (R^*_k); s, the $h \times h$ diagonal matrix (s_k); $\mathbf{T}^*$, the $h \times 1$ vector (T^*_k); $\mathbf{X}$, the $n \times 1$ vector (X_i); $\mathbf{Y}$, the $h \times 1$ vector (Y_k); Ω, the $h \times n$ matrix (ω_{kj}).

Equation (6) is written in the standard closed Leontief form, which solves for all gross outputs and household incomes given the levels of exogenous demands—in this case, deliveries to investment activities and net exports. For some purposes, however, this may not be an appropriate statement of the problem. As we are concerned with the indirect effects of a project, we want household incomes to be endogenous. But in each of the n material balances, we are still free to fix any two of gross output, deliveries to investment and net exports, leaving the third to be determined endogenously; for the system remains linear in $(n + h)$ equations and $(n + h)$ unknowns.

In what follows, investment deliveries are assumed to be exogenously determined by entrepreneurs' "animal spirits" and/or the government's development expenditure programs. This is a departure from previous applications of semi-input-output, which focus on the "complementary bunch" of investments which must take place in the nontradable sectors to support a given increase in the output of a particular traded good—see, for example, Kuyvenhoven. Although our choice is dictated by the absence of data from which a full investment matrix could be estimated, it is still necessary to check, if only in a sketchy way, that the stream of exogenously specified investment deliveries is consistent with the changes in output levels that occur over the relevant period.

This treatment of investment implies that the final choice for "closing" the economic system is between fixing domestic supply (gross output), and fixing net foreign demand (exports). In making this choice, there are two general considerations. First, we may wish to create a fairly comprehensive set of social accounts for some year in the past for which we have only fragmentary information, on the assumption that the parameters of equation (6) estimated from the social accounts of some "base year" are stable. Estimates of exogenous taxes ($\mathbf{T}^*$), transfers ($\mathbf{R}^*$) and investment deliveries ($\mathbf{J}$) for the earlier year are needed. But when it comes to choosing between gross output and net exports, the search for data is eased by recognizing that sectors producing nontraded goods and services must have zero net exports. As for the remaining sectors, piecing together a set of estimates of gross output levels commonly will be a less speculative exercise than doing so for net exports—in the context of a regional economy, at least.

Second, we may be interested in forecasting or in simulating some hypothetical circumstances, such as the absence of the project. Here, whether gross output levels or net exports are made exogenous is not a matter of convenience or reliability in estimation, but rather of one's view as to how the economy works. In the present context, the output trajectories of some tradables are exogenous, having been fixed by decisions made in the past. In these circumstances, net exports must do the adjusting. However, sectors producing nontradables are faced with additional demand from firms and households, and so their outputs will expand also, either by fuller capacity

utilization or, if enough time is allowed, by additions to existing capacity. But excess capacity or not, the key assumption is that the production of nontradables takes place at constant costs, which implies that short-period supply bottlenecks, and hence the rises in prices which accompany them, are ignored. In this respect, the analysis set out is in keeping with the general recommendations concerning the treatment of nontradables offered, e.g., Little and Mirrlees.

The foregoing discussion can be translated into a simple, comparative static account of the development of a regional economy in which the source of growth is the expansion of the primary sector. In each "period," the supply of output from this sector is fixed, and the region faces a perfectly elastic "foreign" demand curve for its products. By contrast, the supply of nontradables is perfectly elastic, and foreign demand for these goods is perfectly inelastic (at zero).

Let the subscripts T, D, and N denote, respectively, the following sets of sectors: tradables, distributive and transport services, and other nontradables. Noting that the set of endogenous variables is the vector ($\mathbf{E}_T$; $\mathbf{X}_D$; $\mathbf{X}_N$; $\mathbf{Y}$), equation (6) can be rearranged as

$$
(7)\quad
\begin{bmatrix} -I & -A_{TD} & -A_{TN} & -B_{TC} \\ -\mu_{DT} & I - A_{DD} & -A_{DN} & -B_{DC} \\ 0 & -A_{ND} & I - A_{NN} & -B_{NC} \\ 0 & -\Omega_D & -\Omega_N & I \end{bmatrix}
\begin{bmatrix} \mathbf{E}_T \\ \mathbf{X}_D \\ \mathbf{X}_N \\ \mathbf{Y} \end{bmatrix}
=
\begin{bmatrix} \Gamma_T u \\ \Gamma_D u \\ \Gamma_N u \\ 0 \end{bmatrix}
+
\begin{bmatrix} J_T \\ J_D \\ J_N \\ 0 \end{bmatrix}
-
\begin{bmatrix} B_T(I-s)T^* \\ B_D(I-s)T^* \\ B_N(I-s)T^* \\ 0 \end{bmatrix}
+
\begin{bmatrix} -I + A_{TT} & 0 & 0 & 0 \\ A_{DT} & 0 & \mu_{DN} & 0 \\ A_{NT} & 0 & I & 0 \\ \Omega_T & 0 & 0 & I \end{bmatrix}
\begin{bmatrix} \mathbf{X}_T \\ \mathbf{0} \\ \mathbf{E}_N \\ \mathbf{R}^* \end{bmatrix},
$$

where μ_{DT} and μ_{DN} are the matrices of distributive and transport margins on the net exports of tradables and nontradables, respectively.[2]

[2] It may happen that some sectors face completely inelastic, albeit positive, "foreign" demand. In that case, they are producing nontradables at the margin and are treated as such in the analysis, the vector of these foreign demands being $\mathbf{E}_N$. It should be noted also that distributive and transport margins are earned on gross rather than net flows, so that the formulation in equation (7) is strictly correct only when there are no competitive imports for those sectors which export. In the empirical application pursued below, that is a defensible approximation to the observed trade patterns.

Equation (7) is the semi-input-output model from which our empirical results were derived.

The Growth of the Regional Economy: 1967–74

Before embarking on a discussion of how the exogenous variables and their values were chosen, two important implicit assumptions in our use of equation (7) should be noted. First, the effects of changes in the structure of relative prices were ignored, although in fact the region's barter terms of trade worsened slightly between 1967 and 1972, before improving strongly over the next two years. But if relative prices are changing, equation (7) will be free of error in generating real value added (measured in units of own output) if, and only if, intermediate inputs form a Cobb-Douglas aggregate in each sector. And even then, there are likely to be substitution effects in household expenditure patterns. It should be noted also that while the exogenous quantity flows that drive (7) are those which occurred at the prices which actually ruled (at one time or another), all inputs and outputs are valued at base year prices. Hence, changes in the barter terms of trade are not allowed to alter the levels of real incomes through the usual effects of changes in prices on nominal value added; they do so only through their effects on the output of tradables. The only alternative to making a foray into the difficult terrain of price endogenous systems is to take the position that these blemishes are the price to be paid in using a tractable system such as (7).

Second, with the two following exceptions, it was assumed that the structural parameters of equation (7) also remained stable in the face of all other influences. First, there were the changes in paddy production technology and the distribution of the sector's value added following the introduction of irrigation and new paddy varieties. Second, there have been changes in the region's population and in the pattern of seasonal migration associated with paddy cultivation.

Where the paddy sector is concerned, the estimates of the technology ($\mathbf{A}_6$) and distribution (Ω_6) vectors are derived largely from a programming model which predicts inputs, output, land rents, and wages, given certain resource endowments and the prices of tradables. The important changes in technology between 1967 and 1974 were the substitution of

mechanical for animal draught power and the more intensive use of fertilizer on new, high-yielding varieties. There was also a marked increase in the proportion of value added paid as wages to migrant laborers from the non-project area and other regions, although the real wage rate rose only slightly. The distribution of value added among households underwent more radical changes, the most noteworthy being the fall in the share of nonproject farm households, which continued to cultivate a single crop, although they did benefit from additional wage earnings within the project area. The shares of output paid as wages to workers from landless and nonfarm households both increased somewhat, while that paid as rents (some of which accrued to rentiers among nonfarm households) stayed virtually constant. These shifts are presented in summary form in table 2.

As for population growth, this affects the demand system by altering the intercept terms, i.e., the $\{\gamma_{ik}\}$, though leaving the marginal expenditure proportions $\{\beta_{ik}\}$ unchanged.[3] The only population data available are contained in the two censuses of 1957 and 1970. The quinquennial growth rates for these two subpopulations were 4.6% and 3.7%, respectively. These rates are assumed to hold for the period 1967–72, because only after 1971 did farm incomes begin to rise strongly in response to the arrival of irrigation; and expectations about alternative income levels, which figure heavily in the decision to migrate, are unlikely to have been revised sharply in the immediate aftermath. It seems plausible that the surge in real incomes between 1971 and 1974 should have done something to stem the outflow of permanent migrants from the region. But in the absence of any evidence, we were reduced to guessing that the farm and nonfarm populations were rising at 1% and 2% per annum, respectively, between 1972 and 1974.

Exogenous Variables for 1967

Recall that an attempt to construct a detailed picture of the economy as it was in the past need take account only of data availability when it comes to choosing between fixing export or output levels for each sector. The sectors comprising the agricultural complex (1–11) all produce tradable goods. With the exception of sector 10, it was possible to derive estimates of gross output. Fortunately, in the case of sector 10, there were relevant data for estimating exports in 1967. The only other sector producing tradables is (14), and once again data were available on its export components. In the remaining sectors, of course, net exports were set at zero, although it should be noted that the output levels of the four government sectors are known and given independently of demand.[4] Deliveries to investment activities are made only by sectors 10, 14, 26, and 27. Again, the sources for the 1972 estimates provided the data for their 1967 counterparts. Of the remaining exogenous variables, net private transfers to households were set at their 1972 levels, these being very small and there being no other basis for a set of

[3] In period t, the expenditure of the kth class of household on the ith commodity is

$$C_{ik}(t) = \gamma_{ik} + \beta_{ik}C_k(t).$$

If the population grows by g_k percent and expenditure per family stays constant, then $C_{ik}(t)$ grows by g_k percent also. If, however, the population is stationary and expenditure per family grows by ϵ_k percent, then

$$C_{ik}(t+1)|_{g=0} = \gamma_{ik} + \beta_{ik}(1+\epsilon_k)C_k(t).$$

Combining the two, we get

$$\begin{aligned} C_{ik}(t+1) &= (1+g_k)\gamma_{ik} + \beta_{ik}[(1+g_k)(1+\epsilon_k)]C_k(t) \\ &= (1+g_k)\gamma_{ik} + \beta_{ik}C_k(t+1). \end{aligned}$$

[4] To be exact, they are completely independent of household incomes, but slightly dependent on activity levels in other sectors through weak interindustry linkages. The allocations to households are given exogenously and the (small) supplies to satisfy interindustry demands are endogenously determined.

Table 2. Household Shares in Gross Output from the Paddy Sector (Ω_5)

Household Class	1967	1972	1974	1974[a]
1 Landless	0.0179	0.0190	0.0207	0.0168
2 Labor abundant	0.1436	0.1442	0.1499	0.1451
3 Land abundant	0.4658	0.4675	0.4859	0.4705
4 Nonproject farm	0.1846	0.1188	0.1138	0.1710
5 Nonfarm	0.0475	0.0540	0.0590	0.0460
Total	0.8594	0.8035	0.8293	0.8494

[a] In the absence of the project.

1967 estimates. Finally, "exogenous" taxes (T^*_k) on households were estimated in the same way as for the 1972 SAM. These taxes take the form of licenses, fees, and duties, and are levied independently of income levels.

Exogenous Variables for 1974

The relevant sectoral outputs, exports, and investment deliveries were estimated in similar fashion to those for 1967. It also should be noted, however, that the treatment of sawmilling for 1974 differed from that for 1967 in that net exports were set at their 1972 level. This choice reflects the fall in the volume of Malaysia's timber exports during the 1974 world recession and accords well with the views expressed by local businessmen. In effect, then, the output of this sector in 1974 was demand-driven. Net private transfers were kept at their 1972 levels, and exogenous taxes on households were estimated on the same basis as before.

The Results

These values of the exogenous variables generate the salient flows in the economy during 1967 and 1974 which are set out in tables 3 and 4, along with their counterparts from the 1972 SAM. Gross output rose by 55% over the seven-year period, the largest absolute contribution being made by the paddy sector, which accounted for about 21% of the total in 1974. Regional value added grew slightly faster than gross output, as output increased at

Table 3. Regional Gross Output and Value Added in 1967, 1972, and 1974 ($10,000 in 1972 Prices)

Sector		1967 (1)	1972 (2)	1974 (3)	1974[a] (4)	$\frac{(3)}{(1)} \times 100$	$\frac{(3)}{(4)} \times 100$
1–9[b]		24,819*	35,553*	42,691*	28,652*	172.0	149.0
10	Other agriculture	1,375	1,782	2,295	1,972	166.9	116.4
11	Sawmilling	736*	990	954	838	129.7	113.8
12	Agr. machinery services	124	257	311	135	250.8	230.4
13	Machinery repairs	472	595	662	460	140.4	143.9
14	Manufacturing not elsewhere classified	1,867	2,141	2,244	1,983	120.2	113.2
15	Road transport	1,196	1,634	1,993	1,513	166.7	131.7
16	Rail transport	64	104	137	89	214.8	153.9
17	Hotels & restaurants	989	1,435	1,823	1,497	184.3	121.8
18	Entertainment	300	468	599	468	199.7	128.0
19	Services not elsewhere classified	77	123	170	112	220.4	151.8
20	Private health	273	349	418	341	153.3	122.6
21	Distributive trades	2,864	4,038	4,835	3,541	168.8	136.5
22	Petty trading	245	326	408	303	166.6	134.7
23	Electricity	377	485	570	494	151.3	115.4
24	Water	186	246	299	249	160.2	120.1
25	Posts & telecommunications	125	229	377	241	253.3	131.5
26	Residential construction	1,066	1,834	1,853	1,317	173.8	140.7
27	Other construction	6,150	3,639	2,166	1,864	35.2	116.2
28–31	Government[c]	6,764*	9,777*	12,445*	12,010*	184.0	103.6
32	Trad. financial services	272	451	595	353	219.0	168.6
33	Modern financial services	171	233	289	157	169.1	184.1
34	Urban housing	1,297	1,825	2,243	1,846	176.7	121.5
35	Rural housing	2,053	2,640	3,186	2,467	155.2	129.1
	Total	53,854	71,154	83,503	62,902	155.1	132.8
	Total Value Added	30,507	41,889	50,575	38,827	165.8	130.3

Note: * Denotes output level fixed exogenously.
Source: The data source for 1972 is Bell et al.
[a] In the absence of the project.
[b] These are, respectively, commercial rice mills, small rice mills, food processing, fish processing, paddy production, fishing, estates rubber, smallholder rubber, rubber processing.
[c] Irrigation, education, health, and other services, respectively.

Table 4. The Level and Distribution of Per Capita Household Incomes (in 1972 prices)

Household Class \ Income	1967		1967[a]		1974		1974[a]	
	Total	Paddy	Total	Paddy	Total	Paddy	Total	Paddy
1 Landless	131	75	130	75	242	166	140	73
2 Labor abundant	180	124	177	124	330	247	199	131
3 Land abundant	297	224	295	224	556	448	326	237
4 Nonproject farm	271	125	269	125	424	147	387	121
5 Nonfarm	697	17	631	17	1,034	40	904	17
All	412	111	387	111	660	204	521	115

[a] In the absence of the project.

a greater-than-average rate in large sectors which have a high ratio of value added to gross output, such as paddy, smallholder rubber, and government. At a more disaggregated level, gross output from the agricultural complex expanded by 70%, noteworthy details being a doubling of paddy production, big jumps in smallholder rubber output (8) and rubber processing (9), and the fact that small-scale rice mills expanded output much more rapidly than commercial ones. Elsewhere in the economy, there were broad gains in transport (15, 16), services and distributive trades (17–22), and utilities (23–25). Residential construction (26) boomed, but there was a steep decline in nonresidential construction (27) as work on the Muda irrigation project tailed off from its 1968 peak. Current outlays by government (28–31) increased substantially.

In aggregate, household incomes grew by just over 7.5% per annum between 1967 and 1974. This rapid rate also was accompanied by significant shifts in income distribution. The incomes of all households in the project area grew at about the same rate. A more rapid growth of incomes accruing to landless households from paddy production was offset by a proportionally larger gain in income from nonpaddy sources accruing to the two classes of "landed" households in the project area. Farm households outside the project boundary were less fortunate, being heavily dependent on a single crop of unirrigated paddy and wage employment in the project area. However, the sharp rise in rubber output from smallholdings kept their incomes growing at a fair rate. The incomes of nonfarm households grew at only two-thirds of the rate enjoyed by farm households in the project command area, but still accounted for 57% of aggregate household incomes in 1974.

Autonomous Growth and the Impact of the Project

Beginning with the accounting, denote the vector $[\mathbf{X}, \mathbf{Y}]$ by $\mathbf{Z}$, and let $\mathbf{Z}^\circ$ stand for the vector of gross outputs and household incomes in the absence of the project. We have the identity

$$(8)\quad \mathbf{Z}_{1974} - \mathbf{Z}^\circ_{1974} \equiv (\mathbf{Z}_{1974} - \mathbf{Z}^\circ_{1967}) - (\mathbf{Z}^\circ_{1974} - \mathbf{Z}^\circ_{1967}).$$

The left-hand side is the net impact of the project in 1974. The first term on the right-hand side is the change in $\mathbf{Z}$ between 1967 and 1974 in the hypothetical event that there had been no project construction work in 1967; and the second term is the set of "autonomous" changes in the regional economy over the period, i.e., the changes that would have occurred had there been no project. Thus, to examine the sources of growth in a "causal" way, we must construct hypothetical pictures of the economy for both years.

1967 without the Project

It may seem that we have complicated the task unnecessarily by choosing a starting year in which project construction was already underway; but the defense is a simple one. The data set on which exogenous variables would be based is very sketchy for earlier years, and we think it better to rest our (minor) hypothetical modifications to 1967 on the relatively secure foundations of the estimated "actuals" than to estimate "actuals" for 1965 (say) on a far shakier data base. We arrived at our hypothetical picture of 1967 by making a change in one exogenous variable of the set generating $\mathbf{Z}_{1967}$: investment deliveries by sector 27 were cut by \$40 million, the dif-

ference being the direct construction demands of the project in that year.

It is worth emphasizing the assumptions which implicitly accompany this change. First, the outputs of sector 1–9 in the agricultural complex are held fixed at their actual levels in 1967, which implies that they were unaffected by the demand for factors arising out of project construction work. This boils down, in essence, to assuming that labor was in perfectly elastic supply, an assumption made plausible by the heavy outmigration from the region between 1957 and 1970. Second, it is unlikely that current government outlays (28–31) would have changed from their 1967 levels. Third, in the cases of the remaining sectors, whose output is demand-driven, there is no problem of output capacity because a cut in exogenous demand will reduce output levels. Fourth, private transfers and lump sum taxes have been left alone. Estimates of the formers' 1967 "actual" values are already tenuous. License fees for vehicles and businesses might have been a little lower in the absence of project construction work, but it is difficult to gauge by how much. Last, a more subtle point: if there had been no construction work on the project, expectations about the future may well have been different, perhaps with important consequences for private investment. This, too, has been skipped over; the error, if any, would be in the direction of overstating regional activity levels and incomes in the hypothetical version of 1967 presented below.

1974 without the Project

The departures of the hypothetical exogenous variables from their actual values in that year are naturally more extensive. The most important of them is, of course, the level of paddy output. The small increase over the 1967 level is largely a reflection of improvements in yields of the main season crop, which would have occurred even if the project had not been undertaken. As for the sector's production technology, compared with 1967 there is no advance in mechanization but more intensive use of agrochemicals. The small declines in the shares in value added of households supplying labor to cultivating households are the result of a slight fall in the paddy wage measured in units of paddy, the nominal wage rate having risen more slowly than the price of paddy but faster than that of the relevant consumption basket.

As the region supplied about 40% of Malaysia's rice needs in 1974, one might also ask whether the price of paddy would have risen even more strongly if the project had not been undertaken. However, the country's source of marginal supplies was imports, principally from Thailand and China, and it does not seem likely that the domestic price, which was close to the c.i.f. price of imports in 1974, would have risen further if there had been no Muda project.

In the agricultural complex, the gross output levels of the two rice-milling sectors have been left at their 1967 levels. As the output of paddy would have increased modestly in the absence of the project and there were small net imports of paddy into the region in 1967, this assumption seems sound. The gross output levels of sectors 3, 4, 6, 7, and 9 were set at their actual values in 1974, which amounts to assuming that, on balance, activity in these sectors was unaffected by the increased demand for domestic factors and goods generated by the project. In the case of smallholder rubber, however, some allowance was made for the fact that seasonal work in paddy production competes with rubber tapping. The level of net exports from sector 10 would have been somewhat lower in the absence of the project. For after 1970, the buffalo herd was being run down rapidly in the face of the advances in mechanization which accompanied the project, and this resulted in an increased supply of animals on the hoof for export. To reflect this, the sector's net exports were set $0.6 million lower than their actual level in 1974. In keeping with the argument in the previous section, net export deliveries from sawmilling were left unchanged at their actual value in 1974. Both the exports of sector 14 and government outlays (29–31) were also left at their 1974 levels.

Turning to investment activities, an inspection of the time series of buffalo livestock between 1967 and 1973 led to a "guesstimate" of zero deliveries from sector 10 to investment activities in 1974 in the absence of the project. Deliveries from sector 14 and government investment in housing were taken as given, but private investment in urban housing was reduced by about 50% to reflect the likely reduction in the demand for urban housing services had the project not been undertaken. Investment in rural housing was derived from the

Table 5. The Composition of Changes in Per Capita Household Incomes Due to the Project ($)

Source of Income Change	Household Class 1	2	3	4	5	Total
Paddy						
output effect	66	108	195	45	15	95
distributive effect	27	8	16	−19	8	−6
Other	9	15	17	13	107	50
Total	102	131	230	37	130	139

expenditures of single-cropping households in 1972. In the case of nonresidential construction, the tail end of Muda project work was cut out, together with a sizable chunk of the (modest) private demand for such output.

Following earlier practice, private transfers were left at their actual levels in 1974. Lump sum taxes were altered to reflect "guestimates" of what the stock of vehicles and the number of businesses would have been in the absence of the project. These changes affected mainly nonfarm households, reducing their tax burden by almost $4.5 million.

The only remaining issue is whether permanent outmigration from the region might have been higher if there had been no project. Although there is no direct evidence on which to base an answer, it seems plausible that the rapid rise in incomes between 1970 and 1974 has induced more people to stay in the region than otherwise would have been the case. In rough and ready fashion, it has been assumed that the farm population would have been stationary after 1972, whereas the nonfarm population would have grown at 0.5% per annum.

The Results

We begin with the net impact of the project at maturity, viz., $\mathbf{Z}_{1974} - \mathbf{Z}^{\circ}_{1974}$, laid out in tables 3 and 4. Regional gross output is about a third higher, fuelled largely by rises in paddy and rice-milling output. Taken as a whole, the agricultural complex accounted for about 70% of the project's net impact on aggregate gross output. For the "demand-driven" group, the heaviest absolute increases occur in sectors 15, 17, 21, 26, 27, 34, and 35. The gain in regional value added due to the project is about 30% of what total value added would have been in the absence of the project. As the absolute gain is $117.5 million, of which $67 million is due to the increase in paddy output, then for every dollar of value added generated directly by the project at maturity, another 75¢ was generated in the form of "downstream" or indirect effects. Within the project boundary, households enjoyed large income gains from the advent of irrigation; farm households on the region's periphery gained somewhat from additional seasonal work in paddy cultivation; and nonfarm households did rather well, especially out of the income-expenditure linkages of the system.

It is also of some interest to decompose the total change in income due to the project at maturity into that derived from paddy production and that from all other sources. And within the former, we distinguish between the pure output effect on incomes assuming that the actual 1974 distribution of value added held in the absence of the project and a distributive effect resulting from changes in the distribution vector Ω_5, where the "distributive" effect is defined as follows: the incomes of household class k from sector j in the two situations are $\omega_{kj}X_j$ and $\omega^{\circ}_{kj}X^{\circ}_j$, respectively. The "output" effect is simply $\omega_{kj}[X_j - X^{\circ}_j]$, and the "distributive" effect, D_k, is a residual defined by: $D_k + \omega_{kj}[X_j - X^{\circ}_j] = \omega_{kj}X_j - \omega^{\circ}_{kj}X^{\circ}_j$, that is, the "output" and "distributive" effects sum exactly to the observed change in income. In aggregate, the "downstream" income increase was almost two-thirds the magnitude of the direct one, and it accrued overwhelmingly to nonfarm households. The nonzero distributive effect in aggregate arose from the fact that the actual 1974 paddy technology was more intensive in its use of intermediate inputs and migrant labor than its hypothetical counterpart, so that the sum of the income parameters $\{\omega_{k5}\}$ was smaller in the presence of the project.

To complete the picture, let us now look at the "autonomous" changes between 1967 and 1974, $(\mathbf{Z}^{\circ}_{1974} - \mathbf{Z}^{\circ}_{1967})$.[5] In the absence of the

[5] The gross output estimates for 1967 in the absence of the project are not reported in table 3. They differ only from their 1967 with project counterparts in that total gross output is 11% less at $480.7 million, the bulk of the discrepancy being in sectors 13, 14, 15, 21, 26, and 34.

project, regional gross output would have increased by about 30%, and value added and household incomes by about 35%. The principal source of autonomous expansion was the increase in government outlays on both current and capital accounts, the former rising over 80% and the latter, which were far smaller, by about 50%. Excluding the agricultural complex, the output of the remaining sectors is demand-driven, so that a failure to undertake the project coupled with static government expenditures under other headings would have resulted in regional production and incomes growing at only half their actual pace over the period. Even so, the autonomous growth pattern would not have been an equitable one. As table 4 makes plain, the principal beneficiaries would have been nonfarm households, whose incomes are well above the regional average. Similarly, the incomes of nonproject farm households would have been buoyed by rising rubber output; but the rises in the incomes of paddy farm households over their 1967 levels would have been of the order of 10%.

Balancing Investments

To complete this analysis of the project's impact on the region, it is necessary to form some estimate of the investment needed to realize the "downstream" effects. At one extreme it could be assumed that all sectors other than that producing paddy were suffering from excess capacity to such an extent that no additional investment was needed to complement the project itself. But this is hardly realistic in the light of the investments in buildings, housing, vehicles, and rice milling which accompanied the surge in incomes after 1970. Unfortunately, the available data provide only a sketchy investment series for the period in question, so the following estimates of investments related to "downstream" effects are inevitably somewhat tentative.

For present purposes, the relevant investment deliveries were made by sectors 14, 26, 27, and imports. An estimate of the investment needed to realize both "autonomous" and "downstream" increases in regional value added is obtained by omitting construction deliveries to the Muda project. Without discounting, this investment reached a cumulative total of $240 million in 1972 prices. Leaving aside additional investments in the rice-milling sectors, which took the form mainly of extra drying capacity to handle a second crop and did not exceed $5 million (FAO/IBRD), it seems plausible that the composition of the investments needed to support "autonomous" growth and "downstream" effects would not be so very different. Now the "autonomous" increase in value added between 1967 and 1974 was $110.4 million, while the "downstream" value added attributable to the project at maturity in 1974 was $50.5 million. Apportioning the $240 million additional investment in the same ratio as that for value added, we arrive at an estimate of $75 million for the cumulative, undiscounted total investment associated with the steady state "downstream" increase in value added.

This estimate is, however, almost certainly on the high side; for much of residential and nonresidential construction was undertaken by the state or federal governments. Moreover, it is unlikely that extra investments were made much in advance of the appearance of the project's "downstream" effects in 1970. Fragmentary evidence suggests that annual private investment in housing and other buildings would have been about $7 million lower in the absence of the project from 1970 onward. Cumulated over four years, this approach yields an estimate of "downstream"-related investments of $38 million. Taking the two estimates together, it seems fairly probable that realizing each dollar of "downstream" value added associated with the project needed between $0.75 and $1.5 of complementary investment appropriately distributed over all other sectors.

Conclusions

It must be emphasized that the frailties of the data base, and the many assumptions thus entailed in deriving results, demand some caution in drawing conclusions from the empirical analysis. Nevertheless, the broad orders of magnitude of certain key variables should be sufficiently solid to warrant some confidence in our main findings. In aggregate, the Muda project's downstream effects were of the same order as its direct effects: for every additional dollar of value added in paddy production generated by the project at maturity, about 75¢ of value added were generated by downstream effects. Also, each dollar of downstream value added probably was supported by just over a dollar of additional investment in plant and

equipment spread appropriately over the sectors which expanded in response to the project. The direct effects of the project did not worsen the distribution of income among farm households, but its downstream added value accrued mainly to the nonfarm households engaged in paddy milling and the production of nontradables. Although the spread in nonfarm incomes was wide, the lion's share of downstream income went almost certainly to households which were better-off than those engaged in paddy farming. Thus, while the project's downstream effects did much to boost the aggregate income of this relatively poor region, they worsened the intraregional distribution of income. Last, it is clear that, "new technology" notwithstanding, the project's production linkages were much weaker than its consumption linkages, for value added in paddy production accounted for more than 80% of gross output. Hence, even allowing for the expansion of paddy milling and agricultural machinery services, the doubling of paddy output injected into the system far more final demand from rising farm incomes than demand for intermediates (with final demand exogenously fixed). While there can be no claim that these findings are typical for all investment projects in LDCs, we believe that they provide a plausible first stab at the parameters for peasant agriculture, at least.

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References

Bell, Clive, Shanta Devarajan, Peter Hazell, and Roger Slade. "A Social Accounts Analysis of the Structure of the Muda Regional Economy." Mimeographed. Development Research Center, World Bank, Washington, D.C., Nov. 1976.

Chenery, Hollis B. "The Interdependence of Investment Decisions." *The Allocation of Economic Resources*, ed. Moses Abramovitz et al. Stanford, Calif.: Stanford University Press, 1959.

Hirschman, Albert O. *The Strategy of Economic Development*. New Haven, Conn., and London: Yale University Press, 1958.

Johnston, Bruce F., and Peter Kilby. *Agriculture and Structural Transformation*. London: Oxford University Press, 1975.

Kuyvenhoven, Arie. *Planning with the Semi-Input-Output Method*. Leiden, Neth.: Martinus Nÿhoff, 1978.

Little, I. M. D., and J. A. Mirrlees. *Project Appraisal and Development Planning for the Developing Countries*. London: Heinemann, 1974.

Mellor, John W. *The New Economics of Growth*. Ithaca, N.Y.: Cornell University Press, 1976.

Pyatt, Graham, Alan R. Roe, and associates. *Social Accounting for Development Planning*. Cambridge: Cambridge University Press, 1977.

Scitovsky, Tibor. "Two Concepts of External Economies." *J. Polit. Econ.* 62(1954):143–51.

Tinbergen, J. "Some Refinements of the Semi-Input-Output Method." *Pakistan Develop. Rev.* 6(1966):243–47.

United Nations. FAO/IBRD Cooperative Program. *The Muda Study: A First Report*. Rome, Sept. 1975.

Price Endogenous Mathematical Programming As a Tool for Sector Analysis

Bruce A. McCarl and Thomas H. Spreen

The question, "Why use a mathematical programming model at the sectoral level?" is addressed. To address this question, discussion is presented mathematically and verbally upon mathematical programming sector models in which both price and quantity are endogenous variables. The discussion covers both the theoretical properties and the empirical concerns which must be faced in applying such models. Discussion is also presented upon the usefulness of the modeling approach for policy analysis. Selected bibliograpic citations' use of the approach in policy analysis are given.

Key words: mathematical programming, policy analysis, sector modeling.

Economists and agricultural economists long have been interested in the use of models as an input to planning and prediction within an economy. This interest has focused with particular intensity upon determining the direct and indirect impacts of alternative policies.

Various methodologies have been utilized to formulate these models. In studies in which the entire economy and, particularly, linkages between sectors are of interest, input-output analysis has been used. In other studies where the objective has involved identification of a sector's structure, various econometric approaches have been taken. To simulate the effect of new policies upon a sector, however, mathematical programming has proven to be a particularly useful tool (Blitzer, Clark, and Taylor review the various approaches).

Large-scale, price-exogenous, linear programming models have been used extensively by agricultural economists to simulate the impact of farm programs upon the agricultural sector (as in the work presented in Heady and Srivistava). These large-scale linear programming models have included the restrictive assumption of fixed market prices or quantities (Heady and Srivistava, p. 420), thereby ignoring the interrelationships of aggregate price and quantity. Sector analyses which recognize price-quantity interrelationships may be treated as spatial and/or intertemporal equilibrium problems. Samuelson (1952) first showed how the problem of partial equilibrium within spatially separated markets could be solved through mathematical programming. Takayama and Judge (1964a, b), using linear, price-dependent, demand and supply functions, extended the Samuelson formulation so that the spatial structure of prices, production, factor use, and consumption were determined with quadratic programming.

Quadratic programming formulations have been used extensively (e.g., Judge and Takayama, Hall et al.). Duloy and Norton (1975), through the use of separable programming, have approximated the quadratic objective function as a linear function enabling the simplex method to be utilized for solution, thereby expanding the size and scope of problems which can be considered.

Despite its widespread use, the arguments for and process of using a mathematical programming sector model are unclear to many. The nature of the objective function in the quadratic programming model, for example, is frequently misunderstood. The objectives of this paper are threefold. First, the paper will present the microeconomic foundations of mathematical programming sector models and the embodied theoretical aggregation processes. Following this, the specification of

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such models is reviewed and discussed and, finally, discussion and a review are presented on the possibilities the formulation provides for policy analysis.

Microeconomic Background and Aggregation

A mathematical programming sector model typically contains activities which represent production and consumption of outputs. In the following sections we first discuss the behavior of an individual producer. Next, a procedure for aggregating individual producers is presented and the behavioral characteristics of aggregate production are discussed. Finally, this is related to the formulation of a quadratic programming sector model.

The Individual Producer

In economic analysis a sector is usually assumed to be made up of a large number of participants, each of whom seeks to optimize some objective. Thus, it is appropriate first to examine the actions of the economic entities comprising the sector of interest. We shall assume that producers and consumers operate in competitive markets for both factors and outputs. The producers produce some number of homogenous outputs and compete for the same factors of production. Assume each producer has a finite set of production processes with each representing a particular way of combining a maximum of n-owned factors with a maximum of m-purchased factors to bring one unit into production. Each production process is assumed to be technically efficient. The producer is assumed to maximize profit in choosing these production processes.

To develop mathematically the producer model (Naylor), define q_k to be level of the kth production process, $k = 1, \ldots, p$. Furthermore, define:

X_{ik} as the use of the ith purchased factor in the kth production process ($i = 1, \ldots, m$; $k = 1, \ldots, p$),

Y_{jk} as the use of the jth owned factor in the kth production process ($j = 1, \ldots, n$; $k = 1, \ldots, p$),

Z_{hk} as the yield of the hth output from the kth production process ($h = 1, \ldots, S$; $k = 1, \ldots, p$),

Y_j as the quantity of the jth owned factor available to the producer ($j = 1, \ldots, n$),

P_h as the market price per unit of the hth output ($h = 1, \ldots, S$),

r_i as the market price per unit of the ith purchased factor ($i = 1, \ldots, m$), and the following conversion coefficients: a_{ik} as the quantity of the ith purchased factor required by one unit of the kth production process ($i = 1, \ldots, m$; $k = 1, \ldots, p$), b_{jk} as the quantity of the jth owned factor required by one unit of the kth production process ($j = 1, \ldots n$; $k = 1, \ldots, p$), c_{hk} as the quantity of the hth output yielded by one unit of the kth production process ($h = 1, \ldots, S$; $k = 1, \ldots, p$).

Assuming constant returns to scale, the producer's profit function can be written as

$$\Pi = \sum_{k=1}^{p} \left(\sum_{h=1}^{S} p_h Z_{hk} - \sum_{i=1}^{m} r_i X_{ik} \right).$$

From the definitions, the following constraints occur:

$$(1) \quad -X_{ik} + a_{ik} q_k = 0 \quad (i = 1, \ldots, m;\ k = 1, \ldots, p),$$

$$(2) \quad -Y_{jk} + b_{jk} q_k = 0 \quad (j = 1, \ldots, n;\ k = 1, \ldots, p),$$

$$(3) \quad Z_{hk} - c_{hk} q_k = 0 \quad (h = 1, \ldots, S;\ k = 1, \ldots, p), \text{ and}$$

$$(4) \quad \sum_{k=1}^{p} Y_{jk} \leq Y_j \quad (j = 1, \ldots, n).$$

Thus, the producer's problem may be formulated as the following linear programming problem:

Max Π,
subject to (1)–(4) above, and

$$q_k, X_{ik}, Y_{jk}, Z_{hk}, \geq 0 \quad (i = 1, \ldots, m;\ j = 1, \ldots, n;\ h = 1, \ldots, S;\ k = 1, \ldots, p).$$

Given the values for all necessary parameters and prices, the problem can be solved easily via linear programming. It will be more instructive, however, to formulate the Lagrangian for this problem.

Let L denote the Lagrangian

$$L = \Pi + \sum_{j=1}^{n} \lambda_j \left(Y_j - \sum_{k=1}^{p} Y_{jk} \right) + \sum_{i=1}^{m} \sum_{k=1}^{p} \nu_{ik} \, (X_{ik} - a_{ik} q_k) + \sum_{j=1}^{n} \sum_{k=1}^{p} \omega_{jk} \, (Y_{jk} - b_{ik} q_k)$$

$$+ \sum_{h=1}^{S} \sum_{k=1}^{p} \sigma_{hk} \, (-Z_{hk} + c_{hk}q_k).$$

Kuhn-Tucker conditions provide the necessary and sufficient conditions for a constrained maximum at q°_k, X°_{ik}, Y°_{jk}, Z°_{hk}, λ°_j, ν°_{ik}, σ°_{hk}, ω°_{jk}. Mathematically, the conditions for this problem are as follows.

Production Activities:

$$\text{(5a)} \quad \frac{\partial L}{\partial q_k} = - \sum_{i=1}^{m} \nu^\circ_{ik} a_{ik} - \sum_{j=1}^{n} \omega^\circ_{jk} b_{jk} + \sum_{h=1}^{S} \sigma^\circ_{hk} c_{hk} \leq 0 \quad (k = 1, 2, \ldots, p),$$

$$\text{(5b)} \quad \frac{\partial L}{\partial q_k} q^\circ_k = 0 \qquad (k = 1, 2, \ldots, p),$$

$$\text{(5c)} \quad q^\circ_k \geq 0 \qquad (k = 1, 2, \ldots, p);$$

Purchased Factors:

$$\text{(6a)} \quad \frac{\partial L}{\partial X_{ik}} = -r_i + \nu^\circ_{ik} \leq 0 \quad (i = 1, 2, \ldots, m;\ k = 1, 2, \ldots, p),$$

$$\text{(6b)} \quad \frac{\partial L}{\partial X_{ik}} X^\circ_{ik} = 0 \quad (i = 1, 2, \ldots, m;\ k = 1, 2, \ldots, p),$$

$$\text{(6c)} \quad X^\circ_{ik} \geq 0 \quad (i = 1, 2, \ldots, m;\ k = 1, 2, \ldots, p);$$

Owned Factors:

$$\text{(7a)} \quad \frac{\partial L}{\partial Y_{jk}} = -\lambda^\circ_j + \omega_{jk} \leq 0 \quad (j = 1, 2, \ldots, n;\ k = 1, 2, \ldots, p),$$

$$\text{(7b)} \quad \frac{\partial L}{\partial Y_{jk}} Y^\circ_{jk} = 0 \quad (j = 1, 2, \ldots, n;\ k = 1, 2, \ldots, p),$$

$$\text{(7c)} \quad Y^\circ_{jk} \geq 0 \quad (j = 1, 2, \ldots, n;\ k = 1, 2, \ldots, p),$$

Outputs:

$$\text{(8a)} \quad \frac{\partial L}{\partial Z_{hk}} = P_h - \sigma^\circ_{hk} \leq 0 \quad (h = 1, 2, \ldots, S;\ k = 1, 2, \ldots, p),$$

$$\text{(8b)} \quad \frac{\partial L}{\partial Z_{hk}} Z^\circ_{hk} = 0 \quad (h = 1, 2, \ldots, S;\ k = 1, 2, \ldots, p), \text{ and}$$

$$\text{(8c)} \quad Z^\circ_{hk} \geq 0^1 \quad (h = 1, 2, \ldots, S;\ k = 1, 2, \ldots, p).$$

If output h is produced under the kth production process ($Z^\circ_{hk} > 0$), equation (8a) will hold with strict equality; thus, P_h equals σ°_{hk}. Substituting for σ°_{hk} in equation (5a) and rearranging gives

$$\text{(9)} \quad \sum_{h=1}^{S} p_h c_{hk} \leq \sum_{i=1}^{m} \nu^\circ_{ik} \, a_{ik} + \sum_{j=1}^{n} \omega^\circ_{jk} b_{jk} \qquad (k = 1, \ldots, p).$$

The sum on the left-hand side of equation (9) represents the return to the producer from one unit of production of the kth production process (the price of the hth output times the quantity produced from one unit of the kth production process). The Lagrangian multipliers ν°_{ik} and ω°_{jk} are the prices imputed to the purchased and owned factors of production. Therefore, the right-hand term represents the imputed resource cost of producing one unit with the kth production process. Then (9) says that the total return from one unit produced under the kth production process must be less than or equal to the total imputed costs from one unit produced under the kth production process. This fairly technical explanation can be interpreted loosely as the well-known marginal condition for profit maximization: continue to supply a product up to the point where price equals marginal cost.

Rewriting (5a) gives

$$\text{(10)} \qquad r_i \geq \nu^\circ_{ik}.$$

Above we noted that ν°_{ik} is the imputed cost of the ith purchased factor used in the kth production process. Equivalently, ν°_{ik} is the imputed marginal value given to the ith purchased factor in the kth production process. Thus, (10) is analogous to the familiar marginal condition: continue to apply a variable factor up to the point where its price equals the value of its marginal product.

Rewriting (7a) gives

$$\text{(11)} \qquad \omega^\circ_{jk} \leq \lambda^\circ_j,$$

where ω°_{jk} is the marginal value imputed to jth owned factor used in the kth production process. λ°_j is the marginal value imputed to the availability of the jth owned factor. Thus, (11) implicitly states that the marginal value of the jth owned factor used in the kth process must

[1] These are not all of the Kuhn-Tucker conditions. The others insure that (a) all constraints are satisfied, (b) all shadow prices are nonnegative, and (c) complementary slackness holds. These conditions have been omitted to shorten the discussion.

be less than or equal to the marginal value imputed to the jth owned factor.

The Aggregate

The above marginal conditions give the rules by which producers make production decisions. Within the competitive framework, individual producers cannot affect factor or product prices. As we direct our attention to the aggregate, the assumption of exogenously determined prices for all factors and outputs is no longer tenable. When producers of a sector are significant consumers of a factor or suppliers of a product, the interrelationship of price and quantity needs to be considered. Assume that the inverse demand relation for the output of the sector exists and is given by

$$(12)\quad P_h = f_h\,(\mathbf{Z}, \Theta), \qquad (h = 1, \ldots, S),$$

where Θ is a vector of exogenous factors and $\mathbf{Z}$ is a mxl vector with elements equaling each commodity's total sector output production.

Further, assume the inverse supply relation for purchased factors to the sector exists and is given by

$$(13)\quad r_i = g_i\,(\mathbf{X}, \Gamma), \qquad (i = 1, \ldots, m),$$

where Γ is a vector of exogenous factors and $\mathbf{X}$ is an mxl vector of total sectoral use of purchased factors.

We may now state the underlying premise for the aggregate model. The production level of each activity should be determined by the first order conditions with which an individual producer will select his production level. Additionally, demand and supply relations should be included. This leads to an aggregate model wherein participants individually behave as small competitive units, yet collectively, price and quantity are endogenous. Therefore, we will now construct conditions that reflect this premise and then develop an optimization model that yields these conditions. This requires a redefinition of variables to include the producer dimension. Let q_{lk} be the level of the kth production process utilized by the lth producer ($l = 1 \ldots, L$; $k = 1, \ldots, p$). Similarly define X_{ilk}, Y_{jlk}, Z_{hlk}, a_{ilk}, b_{jlk}, c_{hlk}. Using these definitions, it follows that the sectoral use of the ith purchased factor and the sectoral supply of the hth output are

$$(14)\quad X_i = \sum_{k=1}^{p} \sum_{l=1}^{L} X_{ilk} \qquad (i = 1, \ldots, m),$$

$$(15)\quad Z_h = \sum_{k=1}^{p} \sum_{l=1}^{L} Z_{hlk} \qquad (h = 1, \ldots, S).$$

We will maintain the assumption that owned factors of production belong to the individual producers, thus Y_{jl} is the endowment of owned factor j to producer l ($j = 1, \ldots, n$; $l = 1, \ldots, L$).

The aggregate conditions will be constructed from the above microconditions. First, rather than output price being a constant, it is now given by the functional relation (12). Assuming a vector of optimal levels of output ($\mathbf{Z}^\circ$), we can now develop an aggregate equation relating price to imputed value analogous to (8a) where $\sigma^\circ{}_h$ is the dual variable from (15).

$$(16)\quad F_h\,(\mathbf{Z}^\circ, \Theta) - \sigma^\circ{}_h \le 0 \qquad (h = 1, \ldots, S).$$

Similarly, an analogous condition to (10), where $\nu^\circ{}_i$ is the dual variable associated with (14), is

$$(17)\quad g_i\,(\mathbf{X}^\circ, \Gamma) \ge \nu^\circ{}_i \qquad (i = 1, \ldots, m).$$

Furthermore, individual producers are price takers equating aggregate price with the price they receive (pay) when they produce an output (consume a factor). The imputed marginal cost at which a producer is willing to sell output is greater than or equal to the aggregate price and the producers imputed value of a factor is less than or equal to its aggregate price. Thus, conditions relating aggregate and microprices need to be imposed:

$$(18)\quad \sigma^\circ{}_h \le \sigma^\circ{}_{hlk} \quad (h = 1, \ldots, S,\ l = 1, \ldots, L,\ K = 1, \ldots, p),$$

$$(19)\quad \nu^\circ{}_i \ge \nu^\circ{}_{ilk} \quad (i = 1, \ldots, m,\ l = 1, \ldots, L,\ K = 1, \ldots, p).$$

Complementary slackness-type conditions also are present for (16)–(19), considering cases where production or factor use is zero.

Assuming that both supply and demand functions are linear, define the demand and supply curves as

$$(20)\quad P_h = G_h - \mathbf{H}_h\,\mathbf{Z} \quad (h = 1, \ldots, S), \text{ and}$$

$$(21)\quad r_i = E_i + \mathbf{F}_i\,\mathbf{X} \qquad (i = 1, \ldots, m),$$

where G_h and E_i are scalers and $\mathbf{H}_h$ and $\mathbf{F}_i$ are row vectors.

Given these definitions, we now follow a procedure suggested by Samuelson (1947) who states: "In some cases . . . it is possible

to formulate conditions of equilibrium as those of an extremum problem" (p. 23). The following optimization model possesses the first-order conditions which are developed above, based upon the aggregation process. Actually, this step requires two assumptions: (*a*) the demand and supply functions must be integrable, and (*b*) the demand and supply functions must be independent of sector activity, i.e., the model must be partial equilibrium. Both of these assumptions will be discussed later.

$$(22)\quad \text{Max } \mathbf{Z}'\mathbf{G} - 1/2\mathbf{Z}'H\mathbf{Z} - \mathbf{X}\,\mathbf{E}' - 1/2\mathbf{X}'F\mathbf{X},$$

subject to

$$-X_{ilk} + a_{ilk}\, q_{lk} = 0 \quad (i = 1, \ldots, m;\ l = 1, \ldots, L;\ k = 1, \ldots, p),$$

$$-Y_{jlk} + b_{jlk}\, q_{lk} = 0 \quad (h = 1, \ldots, S;\ l = 1, \ldots, L;\ k = 1, \ldots, p),$$

$$Z_{hlk} - c_{hlk}\, q_{lk} = 0 \quad (h = 1, \ldots, S;\ l = 1, \ldots, L;\ k = 1, \ldots, p),$$

$$\sum_{l=1}^{L} \sum_{k=1}^{p} X_{ilk} - X_i = 0 \qquad (i = 1, \ldots, m),$$

$$-\sum_{l=1}^{L} \sum_{k=1}^{p} Z_{hlk} + Z_h = 0 \qquad (h = 1, \ldots, S),$$

$$\sum_{k=1}^{p} Y_{jlk} \leq Y_{jl} \quad (j = 1, \ldots, n;\ l = 1, \ldots, L), \text{ and}$$

$$X_{ilk},\ Y_{jlk},\ Z_{hlk},\ q_{lk} \geq 0 \qquad \text{for all } i, j, k, l.$$

In the first order conditions of this problem, the micro dual variables must take on subscripts denoting producers (ν_{ilk}, ω_{jlk}, σ_{hlj}), and new dual variables are introduced associated with equations (14) and (15). The reader, however, can easily verify that by assuming good h is produced ($Z_h > 0$), that the dual variable from (14) equals the product price from the demand curve, and by further assuming that the microunit produces ($Z_{hlk} > 0$), then the equation of price and marginal cost follows as discussed above. Similar arguments could be made for factors. Thus, the formulation implies the microeconomic conditions for production by competitive firms are met.

The objective function no longer represents producer profit. The substitution of price-dependent, product-demand, and factor supply schedules transforms the objective function into a measure of consumer's plus producer's surplus. Consumer's plus producer's surplus or net social benefit is defined as the area between the demand and supply curves to the left of their intersection (Samuelson 1952, Takayama and Judge 1971, p. 108).

The constrained optimization model takes as data production coefficients (a_{ilk}, b_{jlk}, c_{hlk}), availability of owned factors, demand schedules for outputs, and supply schedules for purchased factors. The solution of the model generates an equilibrium price and quantity of outputs, usage patterns for purchased and owned factors, prices of purchased factors, and imputed values of owned factors.

In the derivation of the model, it is assumed that the sector is composed of many competitive microunits, none of which can individually influence output or factor prices. Each producer supplies according to the rule: equate product price to marginal cost of producing one more unit of that product. Thus, the sectoral supply schedule is an "aggregate" marginal cost schedule. Similarly, each producer uses purchased factors according to the rule: equate factor price to marginal value product. Thus, the sectoral derived demand for purchased factors will be an aggregate marginal value product schedule. An important, although obvious point, is that the model does not require supply of outputs or demand for factor schedules. Rather, these schedules are derived or projected internally based upon production possibilities, output demand, and factor supply.

The artificial nature of the objective function must be emphasized. As Samuelson (1952, p. 288) stated: "This magnitude (the objective function) is artificial in the sense that no competitor in the market will be aware of or concerned with it. It is artificial in the sense that after an 'Invisible Hand' has led us to its maximization, we need not necessarily attach any social welfare significance to the result. . . ." Hence, the solution of the quadratic programming problem can be characterized as a simulation of industry behavior under the assumption of competition.

The competitive behavior simulating properties of the model provides a potentially powerful tool for policy makers. Excepting the case of centrally planned economies, the government cannot dictate production patterns that are consistent with its objectives. Thus, through its formulation the model explicitly

recognizes the difference and potential conflict between governmental and producer objectives. The model allows the policy analyst to specify a change designed to meet some governmental objective, and then observe simulated sectoral response to the policy change. The model does not assume that sectoral participants will respond to the government "wants"; rather, each producer optimally adjusts so as to maximize profits. Furthermore, producer adjustment is endogenous to the model.

A Digression on Assumptions

In order to formulate the mathematical programming model at the aggregate level, it was necessary to assume integrability of product demand and factor supply functions and a partial equilibrium setting. The purpose of this section is to offer discussion of these assumptions and point out ways of relaxing them in formulations.

Integrability refers to conditions in which the matrix of first derivatives of the factor supply and product demand functions must be symmetric (Hurwicz and Uzana). This implies that the cross-price effects are equal over all commodity pairs. The implications of this requirement vary depending upon whether one is dealing with supply or demand. Following Zusman, "in the case of supply functions the classical assumptions of the theory of production, in fact, yield the symmetry conditions" (p. 55). However, in the case of demand functions, an individual function (of which the mathematical programming functions are aggregates) "consists of a symmetric substitution term and an income effect term" (p. 55). Thus the cross-price effects need not be symmetric. The assumption of integrability requires symmetric cross-prices effects which implies that the effect of income on consumption is identical across all commodities of interest or zero. A commonly made statement regarding integrability is—so what, even if the quadratic matrix is not symmetric, a symmetric quadratic matrix can be formed which when pre- and post-multiplied by a vector will yield the same produce as gotten when multiplying with the asymmetric matrix. This would be done by averaging the cross-product terms and entering them in the off-diagonal positions. This definitely yields the same product. However, when this approach is followed, the derivatives are altered and the equation of price and marginal cost is no longer a first-order condition. Thus this manipulation, while numerically correct, removes the economic meaning underlying the model.

Models that do not require the integrability assumption can be formulated by incorporating price and quantity variables into the primal formulation (Plessner and Heady). Thus, both price and quantity equilibrium conditions are imposed on the primal formulation, as contrasted with the specification of (22) in which quantity equilibrium conditions are present only in the primal, and price equilibrium conditions are generated as Kuhn-Tucker conditions. In the nonintegrable approach, if factor supply and product demand functions are linear, the formulation can be treated as a linear complementarity programming problem (Takayama and Judge 1971, Stoecker, Polito). The objective function of the nonintegrable formulation no longer represents the area between the aggregate production supply and demand functions or net social welfare. For further discussion, see Takayama and Judge (1971).

The partial equilibrium assumption arises because the formulation does not incorporate the income generated by the sector as a simultaneous shifter of the model's product demand function. If the modeled sector is small relative to the entire economy, this should not be a serious problem. If a major sector or set of sectors is of interest, however, the income generated within that sector may have a major impact on aggregate consumer demand. A formulation which does not require the partial equilibrium assumption has been developed by Yaron, who specified a lagged relationship in which aggregate consumer demand in the current period is a function of aggregate consumer income in the previous period. Norton and Scandizzo relayed this assumption in a simultaneous fashion, developing a general equilibrium model in which demand is rotated as a function of current income. Integrability is also a consequence of the Norton and Scandizzo formulation as an income shifter is explicitly introduced, leaving only the symmetric substitution terms.

Specification of Mathematical Programming Sector Models

The preceding discussion has emphasized the economic logic underlying price endogenous

mathematical programming sector models. In order to apply sector modeling, however, one obviously has to specify activities, constraints, etc. In doing this, certain issues need to be faced concerning empirical specification, dynamics, embodied economic behavior, validation, and computation. We now proceed to discuss these issues. Given the review objective of this paper, the discussion will contain many references to examples of the ways these issues have been handled.

Empirical Specification

The theoretical model developed above explicitly aggregates individual producers. In nearly all empirical work, however, the specification to include every individual producer is an impossible task. To simplify this task, empirical studies have attempted to identify homogenous groups or producers. Each group is then treated as an individual producer. While this approach greatly reduces model size, the aggregation of individuals into homogenous groups introduces aggregation bias. Previous authors have sought conditions under which this "preliminary" aggregation may be done to eliminate or minimize aggregation bias. Theoretical zero aggregation bias explorations include Day 1963a, Miller 1966, Paris and Rausser, and Spreen and Takayama. The conditions proposed by these authors, however, are highly restrictive and have led to other studies which have proposed practical methods to minimize aggregation bias. Sheehy and McAlexander propose that firms should be classified on the basis of the most limiting resource for each product. In an example, they show that use of this classification leads to less aggregation bias than procedures based simply on size and type of firm. Their results are supported by Frick and Andrews. Buckwell and Hazell extend this procedure to multiperiod models. A related paper by Hazell shows how the Buckwell and Hazell criteria were used in the construction of a sector model.

Aggregation questions are not limited only to the grouping of producers. Frequently sector models will have regions in which producers share common resources (e.g., hired labor and land). Regions are most frequently selected because of a mixture of climatological and geographic considerations. Egbert and Kim provide a study that examines errors in aggregation due to spatial specification.

Once a level of aggregation has been chosen, data must be developed. The production possibilities set is the heart of most of the mathematical programming sector models. Data requirements for this set are rather imposing and its development is probably the most time-consuming part of the research effort. These coefficients are formed, most frequently, from averaged farm data obtained via farm surveys or census data in conjunction with primary data collection (for example, see Bassoco and Rendon, Eyvindson). However, several other approaches are possible. First, data may be generated from purely secondary sources (Baumes, Candler 1977), or alternatively, detailed surveys may be designed to yield usable data (Kutcher and Scandizzo 1976b). Data for production also have been formed based upon aggregate data using an approach which attempts to recreate equilibrium (Miller 1978, Fajardo), much like the approach used in input-output analysis.

In addition to data on production, supporting data on factor supply and product demand are required. Product demand schedules typically are obtained through econometric estimation. Demand curve estimates have been made using both own-price elasticities and income elasticities. The income elasticities have been transformed using the Frisch methodology (Frisch, Cappi et al.). Brandt and Goodwin recently have found fault with this procedure. These schedules usually specify price as a function of own quantity only. Duloy and Norton (1975) discuss a formulation in which demand price depends upon more than one commodity. Substitution also is modeled when the demand functions contain off-diagonal terms. The form of product demand curves is most frequently linear, although constant elasticity curves have been incorporated using separable programming techniques (Rodriguez). These linear curves are formed directly by estimation or by taking the elasticity and a known price quantity point, then forming a tangent linear curve.

Factor supply schedules are more difficult to obtain. Land and labor supply schedules in agricultural models are particularly difficult to estimate. Little econometric work has been done to assist in generating these schedules, and, thus, many researchers have assumed perfectly elastic factor supply schedules at the prevailing market price. This assumption may result in the model's output supply schedule being more elastic than the actual supply

schedule. Other approaches include supply curve construction using an assumed elasticity (e.g., Fajardo's land market) or the use of linear programming constraints (e.g., Duloy and Norton's 1973 labor market). When using linear programming constraints for the specification of the supply curve, an important topic that arises is the specification of the minimum value of a resource. Linear programming will either completely use up a resource or drive the value to zero. In a practical sense, resources may have a minimum value in other enterprises or will just not be available for less than a minimum return. Duloy and Norton (1973) specify a reservation wage in the labor market and experiment with alternative numerical specifications.

Another problem faced in specification of factor supply and product demand schedule is the difficulty faced when trying to define a particular market. Due to informal markets and the multitude of market channels, it is often difficult to delineate relevant markets. This problem may be exacerbated as the focus of the modeling effort moves from the farm to the region to the sector, etc. (Kutcher discusses the formation of regional demand curves.)

Dynamic Specification

The development of the time frame to be used in the model can be difficult. Most agricultural applications of this modeling technique have covered annual crops and have thus developed a one-year static equilibrium-type model. However, when dealing with either livestock or perennial crops, the need exists to deal with multiyear consequences. This has been accomplished in three ways. First, average farm budgets have been used (Eyvindson). Second, the system has been assumed to repeat itself at the same level, and multiple year physical budgets have been averaged back to a single year (as suggested by Throsby and done in Brandao). Third, the long-run planning horizon has been partitioned into two parts. These formulations begin with an initial inventory, and a finite number of years is simulated. The inventory at the end of the explicit simulation is valued to reflect expected future returns; discounting and time preference of money also must be considered. Dean and Benedictus have used this approach for a long explicit planning horizon; Spreen, McCarl, and White; and White et al., have used it for shorter explicit horizons. Spreen, McCarl, and White also introduce a demand curve for ending inventory.

When the dynamics of the modeled sector are considered, one must distinguish between complete adjustment and partial adjustment to changes in product prices, factor prices, new technology, etc. Many applications have used supply equations which allow equilibrium adjustment of supply to demand. The dynamic setting generally assumed is in some sense long-run equilibrium (although investment is not generally endogenous). Bassoco and Norton call the dynamic setting short-run equilibrium. Short-run supply equations have been used in some spatial equilibrium studies (Kottke). An alternative approach is the use of a recursive formulation (Day 1963b). The recursive model recognizes that the production process for some commodities is long-term, and thus only partial adjustment can be achieved in the short-run. However, as new price information is received, producers may revise their long-term plans. Thus a recursive programming-model solution may represent the results of a series of plans each in operation for one time period (Spreen, McCarl, White). Another variation of a recursive formation is to employ so-called flexibility constraints to constrain allowable acreages of certain crops (Schaller, Day 1963b). Sahi and Craddock review estimation techniques for the use of flexibility constraints.

Behavioral Specification

Behavioral response to price changes is not always satisfactorily modeled by the competitive behavior assumed above (we will not discuss centrally planned economies; see Kornai). Takayama and Judge (1971), and Duloy and Norton (1979) have both presented formulations in which monopolistic or monopsonistic forms of competition have been assumed. Louwes, Boot, and Wage, and Guise and Aggrey-Mensah provide examples where forms of monopolistic competition have been used. Allen (pp. 200–4) provides examples on how to derive reaction functions for situations in between competitive and monopolistic. These functions could then be used in formulating a model.

Risk and the incorporation of risk aversion is another major behavioral feature which may be included in a sector model. Hazell and

Scandizzo (1974, 1977) have written on this topic and have developed a linear programming approach in which they include risk as an additional cost of production. However, they note that "there are definite problems . . . for exact aggregation . . ." (Hazell and Scandizzo 1974, p. 240), and state that the risk-aversion characteristics must be "suitable averages" (Hazell and Scandizzo 1977, p. 206) of individual risk-aversion characteristics. Thus, the development of the aggregation principles under risk has not yet been fully explored.

Using Hazell and Scandizzo's assumptions, several authors have included risk in sectoral formulations. Basic data needs include a historical time series on gross returns to crops. The underlying assertion is that farmers consider this variability in making acreage decisions. Hazell et al. argue that the descriptive performance of models can be improved considerably by introducing risk-averse behavior, and that biases introduced by ignoring risk can be quite significant. Sectoral work by Simmons and Pomareda; Nieuwoudt, Bullock, and Mathia; and Rodriguez all support these statements.

Risk aversion has been included in microeconomic models via many alternative approaches (Anderson, Hardacker, and Dillon overview this literature). Several of the microapproaches are possible for aggregate specifications. Wicks reviews the general area of aggregate risk specifications.

A final issue involving the behavioral specification of these models concerns the presence of tenancy-type relationships. The incorporation of tenancy-type relations is potentially difficult as various forms of relationships lead to different resource allocations (D. Gale Johnson). Land tenure considerations generally have been ignored in mathematical programming sector models (or the assumption has been made that the owner and tenant operate jointly to maximize farm profits). Several linear programming analyses have been made on the question (e.g., Kutcher and Scandizzo 1976a, and Brandao). Cline also has explored the more aggregate consequences. However, with regard to mathematical programming sector models, this subject is apparently largely untouched. Reportedly Kutcher and Scandizzo (1976b) have done a sector model with consideration of sharecropping. The authors have not, however, examined reports on this research.

Validation

Given a fully specified model, one of the most difficult issues is the answer to the question: Well, now that the model is complete, do we have any confidence in the answers it gives? Validation or verification of these models has been examined by several researchers. Nugent began work on this topic in terms of checks as to whether the model's output corresponded to a known solution. Kutcher did further work validating both activity levels and the shadow prices. Rodriguez continued Kutcher's work. The basic validation tests which have been used involve (*a*) how well the model solution, when specified with base period data, corresponds to the real situation in that base period; (*b*) whether the model feasibly can produce the base period demand quantity; (*c*) how well the model replicates the base period quantity (a test of whether price equals marginal cost); and (*d*) how well the model replicates base period quantities with prices fixed at base period actuals. The validation tests which have been used generally relate to aggregate results. Regional production activities have not been validated systematically in the literature found by the authors. This is most likely because results from an aggregate model generally do not compare well to disaggregate regional production patterns. Linear programming models (and particularly ones which do not consider risk) tend to specialize at the submodel level.

A model which does not pass validation would most likely leave the researcher in a difficult position. These models are conditional normative by nature and are therefore frequently valid by assumption. Tests involving validation have been attempted but when a model is "invalid," the model is usually examined carefully in terms of adequacy of coefficients and/or structure. Usually changes are then made and the model is reexamined for validation (Candler 1979, provides an example of this).

Furthermore, validation of the aggregate results does not totally validate a model. One still must be concerned with the adequacy of the supply and demand curves. Given an equilibrium solution to a problem, the slopes of the curves may be varied quite widely (providing the curve continues to pass through the equilibrium points) and the same equilibrium produced. The supply and demand curves are generally implicitly assumed to be valid by

construct or valid through the process of their generation (i.e., econometric estimation).

The final issue on validation of linear programming models concerns their ability to predict what will happen in periods beyond their base specification. Shumway and associates (Shumway and Chang, Shumway and Talpaz) have investigated the ability of linear programming models for prediction. They conclude the technique to be a feasible method for estimation of the direct and cross elasticities of supply with approximately the same degree of accuracy as single equation econometric models.

Computation

The sheer size of these models can impose itself as an element in the formulation process. For example, Eyvindson, in his discussion of model shortcomings, states on several occasions that a shortcoming could be overcome by adding several hundred constraints. However, the linearization technique employed by Duloy and Norton (1975),[2] the new complementary pivot algorithms (see e.g., Stoecker), and the decomposition algorithms of Polito all provide approaches which allow (or potentially provide) the formulation and solution of much larger and more realistic problems.

Use of Mathematical Programming for Policy Analysis

The preceding discussion has emphasized the economic foundations and specification considerations involved when using mathematical programming sector models. Because of the explicit modeling of individual producer behavior, the technique is intuitively appealing. Even though groups of producers may employ a common set of factors to produce a relatively homogenous set of products, their production may vary implying differing response to governmental actions, availability of new technology, etc. The mathematical programming approach allows each production unit to adjust endogenously its output level and factor use to a change in the economic environment. Thus the power of the approach is revealed. Based upon a microeconomic data base, the response of producers to economic policy changes is simulated by the model. Further, the response to policy conditions which have not been imposed previously can be simulated. (Naturally, one runs the risk in this case that the model does not include the relevant adjustment parameters.) In summary, mathematical programming sector models can be valuable when used in a policy assessment setting. (The referenced policy document by the Mexican Government, Ministry of the Presidency, reinforces this statement.)

Model Specification for Policy Analysis

A principal feature of the modeling structure is its richness in terms of the ability to specify changes in the economic environment. Modifications may be incorporated through specification of new activities, new constraints, changes in right-hand-side values, and factor supply or product demand schedules, each of which will be dealt with briefly below.

New activities. To illustrate the addition of new activities, suppose some subset of firms in the sector is plagued with low levels of production (e.g., peasant farmers in a developing country). Alternative production activities may be specified for these firms which make use of new technology, better management practices, etc. (e.g., Spreen, McCarl, White). The modified model is solved and the analyst observes whether the newly specified activities supplant traditional production practices. Often production alternatives entail substitution of capital inputs for labor or more intensive use of purchased inputs such as fertilizers, improved varieties of seed, or veterinary services. Even though these alternatives result in increased output over traditional production techniques, they may not be profitable. Traditional techniques make extensive use of the peasant's cheapest input, labor; and the peasant's inability to acquire purchased inputs often result in traditional production techniques being more profitable to peasant farmers than "modern" alternatives. The mathematical programming approach allows the analyst to evaluate the system's effect of "modern" production alternatives versus traditional techniques. Thus, potential for adoption by producers and the projected effects on prices and quantities of foods and inputs may be judged. Caution also must be exercised in this situation because the data base from which a model is generated may

[2] Baumes and McCarl have investigated computational features of the Duloy and Norton linearization technique.

consist of farm budgets which reflect major obstacles to adoption, such as lack of infrastructure credit, etc. New technology activities, however, may not reflect these factors. Thus, the model may suggest adoption when it is not possible.

New constraints. Production quotas, export quotas, or restrictions on factor availability can be incorporated through the addition of new constraints (e.g., Taylor and Frohberg). For example, a restriction on aggregate production can be handled easily through specification of a constraint which restricts aggregate production of some commodity to a specified level. The model allows each firm to adjust individually and optimally to the production restriction. Here caution must be exercised regarding the nature of constraints. Linear programming finds the "best" solution within the constraints. Thus, if a constraint is imposed, the model will honor it. The model user must be careful to distinguish between enforceable constraints and "goals." An export quota is potentially enforceable while a minimum level of exports is a goal (producers ordinarily cannot be forced to export).

Right-hand-side changes. Changes in resource availability to the sector, such as land availability or transport capacity, can be incorporated through appropriate adjustments in right-hand-side values (e.g., Shei and Thompson). Suppose that some firms in the sector are geographically separated from consuming regions. The model allows specification of alternative or increased transport from the remote region. Thus, establishment of a new road could be simulated and its impact on aggregated production observed.

Factor supply and product demand modification. The imposition of price ceilings, minimum wage laws, increased taxes, or the introduction of imports can be incorporated through modifications of factor supply or product demand schedules (e.g., Simmons and Pomareda). This characteristic of the model allows one to simulate a wide array of policy instruments available to governments.

Policy Applications

Although the literature in this field has evolved relatively recently, the modeling framework has been used for a wide array of policy questions. The basic form of analysis has been comparative statics. Models generally have been validated for base periods, updated based upon projected shifts in supply and demand, then used to simulate response to and changes induced by policies. Supply response parameters also have been studied. The types of model usages reviewed here can be categorized broadly as foreign trade, commodity policy, input policy, project appraisal, and supply response exploration. A brief review of efforts in these areas is presented below. First, however, we will list briefly the major outputs which would be obtained from a model. For expository purposes, let us assume the model is multiregional, open to trade, containing crop and livestock activities. Given this type of structure, a model solution gives prices and quantities for both products and factors along with stock numbers at both the aggregate and regional levels. Further, the model would give functional and regional income distribution, export and import volumes, sectoral balance of trade, tariff revenues, subsidy expenses, interregional commodity movements, and welfare measures. Depending upon the analysis, other substantive items may be drawn from the model. Policy analysis with a model also creates indirect benefits such as an assessment team with sectoral perspective and a sectorally consistent data base.

Foreign trade. Analysis of foreign trade phenomena within a mathematical programming sectoral model has been done by several authors. The most obvious applications entail examination of a sector's reaction to changes in (*a*) export or import prices (Rodriguez and Fajardo have explored this), (*b*) trade volume restriction quotas (Simmons and Pomerada, Cappi et al., and Fajardo have explored this), and (*c*) changes in export levels (Meister, Chen, and Heady examine this). Less obvious foreign trade analyses include Duloy and Norton's (1973, 1979) explorations of comparative advantage—carried out by bounding exports and finding the shadow price on the export bound (which gives the difference between the export price and domestic cost of the product)—and Jabara's analysis of comparative advantage under risk and undistorted prices (e.g., using the shadow rate of exchange).

Commodity policy. Many research efforts have been carried out under the general topic of commodity policy. Representative of these efforts is the Meister, Chen, and Heady study of price supports or storage policy and Bassoco and Norton's study of price support pro-

grams. Such policies as commodity-specific controls or production subsidies (taxes) also may be simulated.

Input policy. Current environmental concerns have led to several sectoral studies in which quantities of factors like fertilizer have been limited (Taylor and Frohberg; Meister, Chen, Heady). Sensitivity to wage rate increases also has been examined (Simmons and Pomareda, Rodriguez).

Project appraisal. Mathematical programming sector models have been used by Hussain and Inman and Bassoco et al., to select projects which are viable at various rates of return. This has commonly been done in the project analysis literature (Little and Mirrlees). Use of the mathematical sector model, however, allows the effect of output price change (through the demand function) to be included.

Supply response termination. A major use of this class of models has been in deriving output supply response, input demand, factor substitution, and product-product possibilities. Response has been studied both with and without risk consideration. Howell and Bassoco and Norton employ sector models to derive output supply, factor substitution, and input demand relationships. These relations do not perfectly correspond to their theoretical analogues because the experiments (i.e., shifting the demand curve to derive output supply) are done by necessity in a multiproduct model and other things (prices, etc.) are not held constant. Further, due to the stepped nature of the functions arc elasticities are generally derived.

Other Applications

In an area with a literature as voluminous and as dynamic as that discussed herein, it is a major undertaking to reference the major pieces of work. The above sections have attempted to cover partially the literature. This section, however, is designed to add yet more references to the list.

Work in mathematical programming sector models has been extensive. Developing countries, in particular, have received attention. To mention a few, efforts have been done in Mexico (Goreux and Manne, Norton and Solis), Tunisia (Roe), Nicaragua (Fajardo), Northeast Brazil (Kutcher and Scandizzo 1976a, b), Philippines (Rodriguez), Zambia (Candler 1977), Guyana (White et al.), Central America (Cappi et al.), and Thailand (Stoecker, Heady, and Hoffman). Notable among these are the recent studies in Mexico which are summarized in a forthcoming book (Norton and Solis).

In the context of developed countries, a sampling of the research includes Canadian studies of the dairy (Sahi and Harrington) and the overall agricultural sector (Lattimore and Thompson). Work also has been done in England (Hazell), Portugal (Egbert and Kim), and Australia (Walker and Dillon). The U.S. also has received much attention with Heady and associates, in particular, contributing (Heady and Srivistava). Other studies include Miller 1978, Taylor and Frohberg, and Baumes.

In addition to the above citations, there are also several literature reviews and edited volumes which cover (or include) allied work. These include Manne; Neunteuful; Judge and Takayama; Kornai, Heady; Walker and Monypenny; Singh; and Blitzer, Clark, and Taylor.

Toward Optimum Policy

The use of these models for policy analysis and their richness in terms of ability to simulate policy has led many to wonder about the following question. Now, given the applicable set of policy instruments, can "optimum" policy be achieved? These thoughts lead either to misuse of models or to the formulation of difficult optimizing models. A classic example of misuse is one where a research team convinces itself that the country wishes to optimize nutritional production and then the research team replaces (or originally formulates) the objective function to do so. One needs only to wonder how many farmers will forego income to produce calories for the aggregate population to see the fault in this modeling strategy.

Alternatively, the problem can be formulated to maximize government objectives subject to the problem above, i.e., (20) being optimized. This type of formulation has been done by Candler and Norton, who call the area of investigation "multilevel programming." Attempts have been made to develop algorithms for its solution (Candler and Townsley; Fortuny and McCarl). However, these algorithms are rather cumbersome and demanding in terms of computer capacity. In-

formal iterative or search methods also may be used in the quest for optimum policy.

Notwithstanding the ways of finding optimum policy given an objective function, there is the problem of developing the objective function. Clearly, the determination of a unique quantity to maximize is difficult. This problem has been examined to some degree in the control theory area (Rausser and Freebairn). The need for an objective function can be somewhat finessed simply by tracing out the policy space by parametric solution of a model.

Obstacles to Use

The major difficulty with mathematical programming formulation is that its data requirements are extensive. Time, manpower, and financial resources required to construct a detailed model can be overwhelming. Certain authors, e.g., H. G. Johnson, have argued (justifiably, in the authors' opinion) that a highly qualified team is necessary to carry out this research. Available computer services also may be a major constraint. Other authors wonder, particularly in the developing country case, if the effort is an appropriate use of resources, e.g., Langham.

A subtle weakness of this type of model revolves around the institutional question of who will use it. The scope of such a model is quite frequently much wider than any group within a country. Beyond research use, then, there is the question of who will use such a model for policy. This may be a major stumbling block to implementation (Klein and Roe are studying this problem).

Concluding Discussion

This paper has presented a mathematical and verbal discussion of mathematical programming sector models. In the formulation, both price and quantity of factors and products are endogenous variables. This is accomplished through the maximization of the area between the product demand and supply schedules. The optimal solution to the model represents a simulation of the industry under the assumption of perfect competition.

Perhaps the principal question that should be addressed in conclusion is: "Why use this technique?" This question is separable into two aspects. First, why use this objective function in a mathematical programming model? Second, why use a mathematical programming model? The most obvious reason for the use of this objective function over others is its behavioral implications are consistent with theoretical economic behavior of the sectoral participants. Thus, a model with this objective can be used to simulate producer response to policy. To impose the "policy objective function," e.g., maximize employment, would create an idea of the maxima that could be obtained but not how it would be obtained by policies directed toward the sector.

The second question to be addressed is: Why use the mathematical programming approach? Fundamentally, the mathematical programming approach should not be used when simple models can do the task at hand. Following Shumway and Chang, "Apparently greater realism in the LP's specification . . . is required to improve substantially on simple econometric models where the latter are also appropriate" (p. 376). We would like to add to this the qualification that "appropriate" includes the fact that data exists for the econometric model estimation. Thus, a mathematical programming model of the above type is attractive in cases where policy analysis is to be done and projections from historical data are not possible due to lack of a data base adequate for statistical analysis of this policy or due to a lack of historical experience with a policy. The mathematical programming sector model relies upon economic theory, building up from producer level data, formally recognizing the potential conflict between government and producer objectives yielding a consistent set of sectoral results within the context of a policy change.

The development of such a powerful and useful tool can be costly. The data requirements are extensive. If resources do exist, however, development of a mathematical programming sector model can be beneficial to both researchers and policy makers.

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References

Allen, R. G. D. *Mathematical Economics.* London: Macmillan & Co., 1965.

Anderson, J., B. Hardacker, and J. Dillon. *Agricultural*

Decision Analysis. Ames: Iowa State University Press, 1977.

Bassoco, L. M., and Teresa Rendon. "The Technology Set and Data Base for CHAC." *Multilevel Planning: Case Studies in Mexico*, ed. Louis M. Goreux and Alan S. Manne, chap. 4.2. Amsterdam: North-Holland Publishing Co., 1973.

Bassoco, L. M., and R. D. Norton. "A Quantitative Framework for Agricultural Policies." *Programming Studies for Mexican Agricultural Policy*, ed. R. D. Norton and Leopoldo Solis, chap. 5. International Bank for Reconstruction and Development, Develop. Res. Ctr., Washington, D.C., forthcoming.

Bassoco, L. M., Anthony Mutsaers, Roger Norton, and José Silos. "Incorporating Policy Guidelines in the Design of Agricultural Investment Projects." *Programming Studies for Mexican Agricultural Policy*, ed. R. D. Norton and Leopoldo Solis, chap. 16. International Bank for Reconstruction and Development, Develop. Res. Ctr., Washington, D.C., forthcoming.

Baumes, Harry. "A Partial Equilibrium Sector Model of U.S. Agriculture Open to Trade: A Domestic Agricultural and Agricultural Trade Policy Analysis." Ph.D. thesis, Purdue University, 1978.

Baumes, Harry S., and Bruce McCarl. "Linear Programming and Social Welfare: Model Formulation and Objective Function Alternatives." *Can. J. Agr. Econ.* 26(1978):53–60.

Blitzer, Charles R., Peter B. Clark, and Lance Taylor. *Economy-Wide Models and Development Planning*. London: Oxford University Press, 1975.

Brandao, Elizabeth. "Evaluation of New Technologies for Small Farmers in Northeast Brazil." M.S. thesis, Purdue University, 1979.

Brandt, J., and J. Goodwin. "A Test of the Frisch Methodology for Estimating Demand Price Elasticities for Individual Commodities." Unpublished paper, Purdue University, 1978.

Buckwell, Allan E., and Peter B. R. Hazell. "Implications of Aggregation Bias for the Construction of Static and Dynamic Linear Programming Supply Models." *J. Agr. Econ.* 23(1972):119–34.

Candler, Wilfred. Private communication on Zambia work. Development Research Center, International Bank for Reconstruction and Development, Washington, D.C., Dec. 1977.

———. "A Demonstration Model for the Dairy Industry of La Laguna." *Programming Studies for Mexican Agricultural Policy*, ed. R. D. Norton and Leopoldo Solis, chap. 17. International Bank for Reconstruction and Development, Develop. Res. Ctr., Washington, D.C., forthcoming.

Candler, W. V., and R. Norton. "Multilevel Programming." Disc. Pap. No. 20, International Bank for Reconstruction and Development, Develop. Res. Ctr., Jan. 1977.

Candler, W. V., and R. Townsley. "A Linear Two-Level Programming Problem." International Bank for Reconstruction and Development, Develop. Res. Ctr., Washington, D.C., forthcoming (1979).

Cappi, C., L. Fletcher, R. Norton, C. Pomareda, and M. Wainer. "A Model of Agricultural Production and Trade in Central America." *Economic Integration in Central America*, ed. W. Cline and E. Delgado. Washington, D.C., The Brookings Institution, 1978.

Cline, W. R. *Economic Consequences of a Land Reform in Brazil*. Amsterdam: North-Holland Publishing Co., 1970.

Day, R. H. "On Aggregating Linear Programming Models of Production." *J. Farm Econ.* 45(1963a):797–813.

———. *Recursive Programming and Production Response*. Amsterdam: North-Holland Publishing Co., 1963b.

Dean, G., and M. de Benedictus. "A Model of Economic Development for Peasant Farms in Southern Italy." *J. Farm Econ.* 46(1964):295–312.

Duloy, John H., and Roger D. Norton. "CHAC: A Programming Model of Mexican Agriculture." *Multilevel Planning: Case Studies in Mexico*, ed. L. Goreux and A. Manne. Amsterdam: North-Holland Publishing Co., 1973, pp. 291–337.

———. "The CHAC Demand Structure." *Programming Studies for Mexican Agricultural Policy*, ed. R. D. Norton and L. M. Solis. International Bank for Reconstruction and Development, Develop. Res. Ctr., Washington, D.C., 1979.

———. "Prices and Incomes in Linear Programming Models." *Amer. J. Agr. Econ.* 57(1975):591–600.

Egbert, A. C., and H. M. Kim. "Analysis of Aggregation Errors in Linear Programming Planning Models." *Amer. J. Agr. Econ.* 57(1975):292–301.

Eyvindson, R. "A Model of Interregional Competition in Agriculture Incorporating Consuming Regions, Producing Areas, Farm Size Groups and Land Classes." Ph.D. thesis, Iowa State University, 1970.

Fajardo, D. "Policy Analysis of Nicaraguan Agriculture: A Mathematical Programming Approach." M.S. thesis, Purdue University, 1977.

Fortuny-Amat, J., and Bruce McCarl. "Multilevel Programming." Unpublished paper, Purdue University, 1979.

Frick, George E., and R. A. Andrews. "Aggregation Bias and Four Methods of Summing Farm Supply Functions." *J. Farm Econ.* 47(1965):696–700.

Frisch, R. "A Complete Scheme for Computing All Direct and Cross Demand Elasticities in a Model with Many Sectors." *Econometrica* 27(1959):177–96.

Goreux, L. M., and Alan S. Manne. *Multilevel Planning: Case Studies in Mexico*. Amsterdam: North-Holland Publishing Co., 1973.

Guise, J. W. B., and W. Aggrey-Mensah. "An Evaluation of Policy Alternatives Facing Australian Banana Producers." *Studies in Economic Planning over Space and Time*, ed. G. G. Judge and T. Takayama. Amsterdam: North-Holland Publishing Co., 1973.

Hall, H. H., E. O. Heady, A. Stoecker, and V. A. Sposito. "Spatial Equilibrium in U.S. Agriculture: A Quadratic Programming Analysis." *SIAM Review* 17(1975):323–38.

Hazell, P. B. R. "Specification of the Newcastle Model of U.K. Agriculture." Unpublished paper, Agricultural Adjustment Unit, University of Newcastle-upon-Tyne, England, 1972.

Hazell, P. B. R., R. D. Norton, M. Parthasarthy, and C. Pomareda. "The Importance of Risk in Agricultural Planning Models." *Programming Studies for Mexican Agricultural Policy*, ed. R. D. Norton and Leopoldo Solis, chap. 8. International Bank for Reconstruction and Development, Develop. Res. Ctr., Washington, D.C., 1979.

Hazell, P. B. R., and P. L. Scandizzo. "Competitive Demand Structure under Risk in Agricultural Programming Models." *Amer. J. Agr. Econ.* 56 (1974):235–44.

———. "Farmers Expectations, Risk Aversion, and Market Equilibrium under Risk." *Amer. J. Agr. Econ.* 59(1977):204–9.

Heady, E. O., ed. *Economic Models and Quantitative Methods for Decisions and Planning in Agriculture.* Ames: Iowa State University Press, 1971.

Heady, Earl O., and U. K. Srivistava. *Spatial Sector Programming Models in Agriculture.* Ames: Iowa State University Press, 1975.

Howell, Hunt. "Machinery-Labor Substitution in Mexico's Central Plateau." *Programming Studies for Mexican Agricultural Policy*, ed. R. D. Norton and Leopoldo Solis, chap. 13. International Bank for Reconstruction and Development, Develop. Res. Ctr., Washington, D.C., forthcoming.

Hurwicz, L., and H. Uzawa. "On the Integrability of Demand Functions." *Preferences, Utility and Demand, a Minnesota Symposium*, ed. J. S. Chipman, L. Hurwicz, Marcel K. Richter, Hugo F. Sonnenschein, p. 114. New York: Harcourt, Brace, & Co., 1971.

Hussain, Tariq, and Richard Inman. "A Model for Estimating the Effects of Credit Pricing on Farm Level Employment and Income Distribution." World Bank Staff Work. Pap. No. 261, July 1977.

Jabara, Cathy. "Agricultural Comparative Advantage under Uncertainty: The Case of Senegal." Ph.D. thesis, Purdue University, 1979.

Johnson, D. Gale. "Resource Allocation under Share Contracts." *J. Polit. Econ.* 58(1950):111–23.

Johnson, H. G. "Planning and the Market in Economic Development." *Pakistan Econ. J.* 8(1958):44–55.

Judge, George G., and Takashi Takayama. *Studies in Economic Planning over Space and Time.* Amsterdam: North-Holland Publishing Co., 1973.

Klein, H., and T. Roe. "Institutional Factors Affecting the Adoption of Agricultural Sector Analysis Methodology in LDCs." Staff Pap. P78-10, University of Minnesota, July 1978.

Kornai, J. *Mathematical Planning of Structural Decisions.* Amsterdam: North-Holland Publishing Co., 1975.

Kottke, Marvin W. "Allocation of Milk through Space and Time in a Competitively Mixed Dairy Industry." *Studies in Economic Planning over Space and Time*, ed. G. G. Judge and T. Takayama, pp. 557–78. Amsterdam: North-Holland Publishing Co., 1973.

Kutcher, Gary. "A Regional Agriculture Planning Model for Mexico's Pacific Northwest." *Programming Studies for Mexican Agricultural Policy*, ed. R. D. Norton and Leopoldo Solis, chap. 11. International Bank for Reconstruction and Development, Develop. Res. Ctr., Washington, D.C., 1979.

Kutcher, Gary, and P. L. Scandizzo. "A Partial Analysis of Share Tenancy Relationships in North East Brazil." *J. Develop. Econ.* 3(1976a):343–54.

———. "The Northeast Brazil Modeling Effort: A Progress Report." Mimeographed. International Bank for Reconstruction and Development, Develop. Res. Ctr., Washington, D.C., 1976b.

Langham, M. R. "On Systems Models for Agricultural Sector Analysis and Research Priorities for Developing Countries." Dep. Food and Resour. Econ. Staff Pap. No. 83, University of Florida, April 1978.

Lattimore, R., and R. Thompson. "A General Equilibrium Trade Model for Canada with Emphasis on the Food Sector." Unpublished draft, Agriculture Canada, Ottawa, March 1976.

Little, I. M. D., and J. A. Mirrlees. *Project Appraisal and Planning for Developing Countries.* New York: Basic Books, 1974.

Louwes, S. L., J. G. G. Boot, and S. Wage. "A Quadratic Programming Approach to the Problem of the Optimal Use of Milk in the Netherlands." *J. Farm Econ.* 45(1964):309–17.

Manne, A. S. "Multi-sector Models for Developed Planning: A Survey." *J. Develop. Econ.* 1(1974):43–70.

Meister, Anton D., Carl C. Chen, and Earl O. Heady. *Quadratic Programming Models Applied to Agricultural Policies.* Ames: Iowa State University Press, 1978.

Mexican Government, Ministry of the Presidency. "A Program for Mexican Agriculture." *Programming Studies for Mexican Agricultural Policy*, ed. R. D. Norton and Leopoldo Solis, chap. 6. International Bank for Reconstruction and Development, Develop. Res. Ctr., Washington, D.C., forthcoming (1979).

Miller, Tom. Private communication regarding USDA sector modeling work. USDA-ESCS, Colorado State University, Jan. 1978.

———. "Exact Aggregation in Linear Programming." *Agr. Econ. Res.* 18(1966):52–57.

Naylor, Thomas H. "The Theory of the Firm: A Comparison of Marginal Analysis and Linear Programming." *S. Econ. J.* 32(1966):263–74.

Neunteufel, M. "The State of the Art in Modeling of Food and Agricultural Systems." Res. Memo. 77-27, International Institute for Applied Systems Analysis, Luxemburg, June 1977.

Nieuwoudt, W. L., J. B. Bullock, and G. A. Mathia. "An Economic Evaluation of Alternative Peanut Policies." *Amer. J. Agr. Econ.* 53(1976):485–95.

Norton, Roger D., and Pasquale L. Scandizzo. "Market Equilibrium Computations in Activity Analysis Models." Draft. International Bank for Reconstruction and Development, Washington, D.C., April 1979.

Norton, R. D., and L. M. Solis. *Programming Studies for Mexican Agricultural Policy.* International Bank for Reconstruction and Development, Develop. Res. Ctr., Washington, D.C., forthcoming.

Nugent, J. B. "Linear Programming Models for National Planning: Demonstration of a Testing Procedure." *Econometrica* 38(1970):831–55.

Paris, Q., and G. Rausser. "Sufficient Conditions for Aggregation of Linear Programming Models." *Amer. J. Agr. Econ.* 55(1973):659–65.

Plessner, Y., and E. O. Heady. "Competitive Equilibrium Solutions with Quadratic Programming." *Metroeconomica* 17(1965):117–30.

Polito, Joseph. "Distribution Systems Planning in a Price Responsive Environment." Ph.D. thesis, Purdue University, 1977.

Rausser, G. C., and J. W. Freebairn. "Estimation of Policy Preference Functions: An Application to U.S. Beef Import Policy." *Rev. Econ. and Statist.* 56(1974):437–39.

Rodriguez, G. R. "The Consideration of Risk in Agricultural Policies: The Philippine Experience." Ph.D. thesis, Purdue University, 1978.

Roe, T. Private communication regarding Tunisian sector model and institutionalization research. University of Minnesota, Aug. 1978.

Sahi, R. K., and W. J. Craddock. "Estimation of Flexibility Coefficients for Recursive Programming Models—Alternative Approaches." *Amer. J. Agr. Econ.* 56(1974):344–50.

Sahi, Ram K., and David H. Harrington. "A Policy Analysis Model for the Canadian Dairy Industry." Contributed Paper, AAEA Annual Meeting, Columbus, Ohio, 10–13 Aug. 1975.

Samuelson, Paul A. *Foundations of Economic Analysis.* Cambridge, Mass.: Harvard University Press, 1947.

———. "Spatial Price Equilibrium and Linear Programming." *Amer. Econ. Rev.* 42(1952):283–303.

Schaller, W. N. "A National Model for Agricultural Production Response." *Agr. Econ. Res.* 20(1968):33–46.

Sharples, Jerry A., and W. Neill Schaller. "Predicting Short-Run Aggregate Adjustment to Policy Alternatives." *Amer. J. Agr. Econ.* 50(1968):1523–36.

Sheehy, S. J., and R. H. McAlexander. "Selection of Representative Benchmark Farms for Supply Estimation." *J. Farm Econ.* 47(1965):681–95.

Shei, Shun-Yi, and Robert L. Thompson. "The Impact of Trade Restriction Price Stability in the World Wheat Market." *Amer. J. Agr. Econ.* 59(1977):628–38.

Shumway, C. R., and A. A. Chang. "Linear Programming vs. Positively Estimated Supply Functions—An Empirical and Methodological Critique." *Amer. J. Agr. Econ.* 59(1977):344–57.

Shumway, C. R., and H. Talpaz. "Verification of Linear Programming Solutions with Emphasis on Supply Implications." *S. J. Agr. Econ.* 9(1977):1–8.

Simmons, R. L., and C. Pomareda. "Equilibrium Quantity and Timing of Mexican Vegetable Exports." *Amer. J. Agr. Econ.* 57(1975):472–79.

Singh, I. "Recursive Models of Agricultural Development." *Studies in Economic Planning Over Space and Time,* ed., G. G. Judge and T. Takayama. Amsterdam: North-Holland Publishing Co., 1973.

Spreen, Thomas H., Bruce A. McCarl, and T. Kelley White. "A Recursive Linear Programming Model of the Cattle Subsector of Guyana." Unpublished paper, Dep. Agr. Econ., Purdue University, 1977.

Spreen, Thomas H., and Takashi Takayama. "A Note on Aggregation Problems of Linear Programming Models of Production." *Amer. J. Agr. Econ.* 61(1979):146–151.

Stoecker, A. "A Quadratic Programming Model of United States Agriculture in 1980." Ph.D. thesis, Iowa State University, 1974.

Stoecker, A., E. O. Heady, and R. A. Hoffman. "Fourth Annual Report: Agricultural Sector Analysis in Thailand." DAE-CARD Sector Analysis, Series No. 12, Iowa State University, Aug. 1978.

Takayama, T., and G. G. Judge. "Equilibrium among Spatially Separated Markets: A Reformulation." *Econometrica.* 32(1964a):510–24.

———. "An Interregional Activity Analysis Model of the Agricultural Sector." *J. Farm Econ.* 49(1964b):349–65.

———. *Spatial and Temporal Price and Allocation Models.* Amsterdam: North-Holland Publishing Co., 1971.

Taylor, C. Robert, and Klaus K. Frohberg. "The Welfare Effects of Erosion Controls, Banning Pesticides, and Limiting Fertilizer Application in the Corn Belt." *Amer. J. Agr. Econ.* 59(1977):25–36.

Throsby, C. D. "Stationary State Solutions in Multi-Period Linear Programming Problems." *Aust. J. Agr. Econ.* 11(1967):192–98.

Walker, N., and J. L. Dillon. "Development of an Aggregative Programming Model of Australian Agriculture." *J. Agr. Econ.* 27(1976):243–47.

Walker, N., and R. Monypenny. "Lineary Programming as a Tool for Agricultural Sector Analysis." *Rev Mktg. and Agr. Econ.* 44(1976):165–78.

White, T. K., B. A. McCarl, R. D. May, and T. H Spreen. "A Systems Analysis of the Guyanese Livestock Sector." *J. Agr. Systems.* 3(1978):47–66.

Wicks, John A. "Alternative Approaches to Risk in Aggregative Programming: An Evaluation." *Europ Rev. Agr. Econ.* 5(1978):159–73.

Yaron, D. "Incorporation of Income Effects into Mathematical Programming Models." *Metroeconomica* 19(1967):141–60.

Zusman, Pinhas. "The Stability of Interregional Competition and the Programming Approach to the Analysis of Spatial Trade Equilibria." *Metroeconomica* 21(1969):45–57.

tration levels in excess of 3%, there could be substantial adjustments relative to the 1947 intensity level. Consider the case for $C = 20$. Advertising intensity would have increased 125% over that of 1947 with no change in concentration. What is apparent in figure 3 is the increased importance of advertising across most industry structures.

Conclusion

The estimates in table 2 provide strong support to the positive relationship between advertising and concentration. A mapping of the empirical results back to table 1 provides some insight as to the alternative effects concentration may have had on both ϵ_a and ϵ_d. Clearly, the alternatives to the right of the diagonal in table 1 are now deleted. The argument that advertising is reduced as concentration increases could only occur if advertising is substituted for price competition indicating that $\partial|\epsilon_d|/\partial C < 0$. It does, however, appear somewhat contradictory to argue that advertising declines in response to rival advertising and simultaneously argue that advertising is substituted for price competition. In contrast, the positive relationship between intensity and concentration is consistent with increases in advertising effectiveness (i.e., $\partial\epsilon_a/\partial C > 0$) and increased nonprice competition (i.e., $\partial|\epsilon_d|/\partial C < 0$). While the empirical evidence is clear as to the final intensity response, conclusions relating to the elasticity response are still tentative.

The empirical evidence failed to show any unique adjustments for food industries that differed significantly from the broader category of durable and nondurable products. Advertising intensity has increased across all concentration levels. The model does facilitate separation of the importance of advertising among manufacturing industries as a result of structural change within industries versus technical changes with the advertising industries where at least part of the shifts over time are due to technical changes in the advertising industry. It is relatively easy to calculate how much of the adjustment in intensity was due to concentration changes versus the time proxy variable. This in turn suggests where public advertising policy emphasis should be directed, assuming that such policy exists and/or is needed. Likewise, the significant difference between consumer and producer goods suggests that if greater governmental scrutiny of advertising is forthcoming, it most likely will be directed toward the consumer goods industries.

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References

Blair, John. *Economic Concentration.* New York: Harcourt, Brace & Co., 1972.

Brush, Brian. "Errors in the Measurement of Concentration and the Advertising-Concentration Controversy." *S. J. Econ.* 44(1978):978–85.

Maddala, G. S. *Econometrics.* New York: McGraw-Hill Book Co., 1977.

Mann, Michael H. "Advertising, Concentration, and Profitability: The State of Knowledge and Directions for Public Policy." *Industrial Concentration: The New Learning.* Boston: Little, Brown & Co., 1974.

Needham, Douglas. *The Economics of Industrial Structure Conduct and Performance.* New York: Holt, Rinehart & Winston, 1978.

Nelson, Phillip. "The Economic Value of Advertising." *Advertising and Society.* New York: New York University Press, 1974.

Ornstein, Stanley. *Industrial Concentration and Advertising Intensity.* Washington, D.C.: American Enterprise Institute for Public Policy, 1977.

Schmalensee, Richard. *The Economics of Advertising.* Amsterdam: North-Holland Publishing Co., 1972.

Shepherd, William G. *Market Power and Economic Welfare.* New York: Random House, 1970.

Strickland, Allyn, and Leonard Weiss. "Advertising, Concentration, and Price-Cost Margins." *J. Polit. Econ.* 84(1976):1109–21.

Ward, Ronald W. "Revisiting the Dorfman-Steiner Static Advertising Theorem: An Application to the Processed Grapefruit Industry." *Amer. J. Agr. Econ.* 57(1975):500–04.

Distribution Cost Reduction as an Incentive for Coal Conversion

Jerry E. Fruin, Richard A. Levins, and Douglas Wilson

Declining natural gas supplies and uncertainty over future oil supplies have led to a federal energy policy of encouraging increased coal use. Administration policies have so far been confined to direct orders requiring electric generating stations and very large industrial plants to use coal. However, financial incentives to reduce the high capital costs required to convert from gas or oil to coal also have received wide discussion.

On the other hand, action to encourage conversion to coal by reducing its delivered cost has received relatively little attention. This is surprising, as annual coal costs will greatly exceed the amortized capital cost of coal conversion at a typical installation. Cost of coal at the mine may not be the most important consideration in reducing delivered coal prices. For example, in Minnesota the transportation and related handling costs of coal are usually greater than the price of coal at the mine.

This paper will examine the extent to which delivered coal prices in southern Minnesota (fig. 1) could be reduced if a more efficient coal distribution system were established for potential users. The effect of such action on the economic attractiveness of coal conversion then will be compared to those of public subsidies to reduce initial conversion costs. It will be shown that the financial equivalent of large direct subsidies for coal conversion can be achieved through gains in coal distribution efficiency at less expense to the general public.

Coal Use and Distribution in the Study Area

Coal use in southern Minnesota is currently 4.7 million tons per year. Most of the coal is used by a small number of electrical generating plants. The 1985 coal use in the study area could grow to 15.7 million tons annually when natural gas is curtailed to some 300 industrial and commercial users who now rely on oil or propane as an alternative fuel. Of the potential 1985 demand, 13.6 million tons already are committed. The remaining 2.1 million tons are potential coal use by 300 natural gas users who must decide among fuel oil, propane, and coal as their gas supplies are curtailed.

Most of the coal currently used in southern Minnesota is from the Powder River Basin in Montana and Wyoming or from southern Illinois and western Kentucky. Coal from eastern sources has been declining in relative importance, primarily because of its high sulfur content and relatively high price. The analyses in this paper assumes that the trend to western coal will continue and that new coal users will be supplied by mines in Montana and Wyoming.

Virtually all of the coal leaving Montana and Wyoming moves by rail. Many large-volume natural gas and petroleum customers cannot receive fuel by rail and would have to take delivery by truck if they converted to coal. However, existing coal terminals in the Twin Cities area with train-to-truck transloading capabilities are operating at or near their permitted capacities. Without expansion in terminal capacity, this group of potential coal customers cannot convert to coal no matter what financial incentives they may be offered.

Most of the potential coal customers who can receive coal by rail face high rail rates because their individual coal consumption is too low for them to qualify for volume rates. The trainload and unit train rates shown in table 1 are 50% to 60% of the single car or 15-car rates.[1] Major savings are available to shippers who have access to such rates. In fact, the difference in cost between the single car and unit train rate is greater than the cost of the coal at the mine.

Transshipping Terminals

A central coal terminal serving several smaller users conceivably could generate sufficient volume to qualify for unit train rates. However, a substantial investment in high speed unloading equipment is required in order to take advantage of the unit train concept. The minimum capital cost of a facility that can handle unit trains and store and transship or process a single grade of coal approaches $8

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[1] A unit train is a dedicated set of locomotives and cars that remain together from origin to destination and travel at high speeds. Time requirements for loading and unloading are minimal. Major operating and administrative efficiencies are obtained. Trainload shipments provide similar, though smaller, savings.

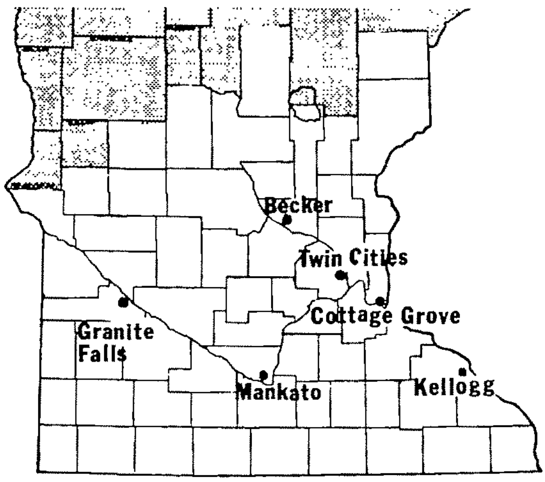

Figure 1. Map of Minnesota study area (unshaded) showing Twin Cities and five possible coal terminal sites

million. Fruin and Crnkovich (1978b) have estimated the minimum capital cost of a rail to truck transshipping facility that can receive, process, and store several grades of coal to be $10 million.

The minimum capital cost of transshipping facilities with both rail-to-truck and rail-to-water was estimated at 12 to 15 million dollars.

Delivery from such a terminal would eliminate the difficulty faced by those customers who cannot receive coal by rail. For coal users who can receive rail shipments, trucking from a central terminal may in many cases be less expensive than paying single-car rail rates for direct shipments from the mines.

An example of the savings possible with such a facility is shown in table 2. The annual cost of owning and operating a facility to transship coal from trains to trucks at an annual volume of 2 million tons per year was estimated to be $1.04 per ton (table 3). The published common carrier rate of $1.85 per ton from the Twin Cities to Elk River, Minnesota (about 35 miles from the center of the Twin Cities) was used to estimate the maximum trucking cost from a centrally located transshipping facility to points in the greater metropolitan area.

Table 1. Coal Rates from Colstrip, Montana, to Selected Destinations in Minnesota

Destination	Type of Shipment	Rate ($/ton)
Minneapolis/ St. Paul	Single car	14.06
Minneapolis/ St. Paul	15 car	13.52
Minneapolis/ St. Paul	105 car trainload	7.61[a]
Becker	Unit train	6.07[b]

Source: Fruin and Crnkovich, 1978b.
[a] Requires 1.1 million tons minimum annual volume. Train must be loaded in less than four hours and unloaded in less than 24 hours.
[b] Requires 2.8 million tons minimum annual volume. Maximum loading and unloading time is four hours.

Table 2. Delivered Cost of Coal to Twin Cities Area Industrial Users from Montana

Cost Item	With Terminal	Without Terminal
	------ ($/ton)	------
Coal, F.O.B. Montana	8.75[a]	8.75[a]
Single car rail shipment	—	14.06
Trainload rail shipment	7.61	—
Transshipping	1.04[b]	—
Trucking	1.85	—
Total	19.25	22.81

[a] *Coal Week*, 21 Aug. 1978. Coal heating value of 8,400 BTU/lb.
[b] Assumes 2 million tons per year throughput.

Even with the extra costs for transshipping and trucking, coal can be delivered for $3.56 per ton less through the terminal than by direct, single-car, rail shipments. The savings may be greater as the rail rate used is an existing trainload rate and not the true unit train rate that would be available if a rail loop and high speed dumping equipment were available. In addition, truck costs would be less to locations nearer the terminal.

Linear Programming Analysis of Terminal Location

The large capital investment required for a unit train terminal makes the transshipping cost quite sensitive to the annual throughput level. At a low annual volume, terminal costs can be high enough to cancel the savings in rail rates. Furthermore, the exact location of the facility is very important as it is necessary to provide lower costs to a large number of potential customers. Customers too far from the terminal will find that higher trucking costs make transshipping uneconomical.

A linear programming model was developed to determine the economic feasibility of potential locations for a new transshipment terminal in the study area, and to estimate the potential savings in delivered coal costs with such a terminal.

Five sites were selected as possible locations for rail-to-truck coal transshiping terminals (see fig. 1). Becker was chosen because a large coal-fired electric generating station with unit-train unloading capabilities is already located there. With additional equipment, the existing terminal could serve smaller customers as well as the power plant. Three of the other sites, Granite Falls, Mankato, and Kellogg, are possible locations for new coal-fired electric generating plants. Terminals could be designed to serve both the power plants and other users. The

Table 3. Estimates of Rail-to-Truck Coal Transshipping Costs for Selected Annual Volumes

Terminal Throughput	Fixed Cost[a]	Variable Costs	Total Transshipping Costs
(1,000 tons per year)			($/ton)
400	3.30	.53	3.83
800	1.65	.48	2.13
1,200	1.10	.48	1.58
1,600	.82	.39	1.21
2,000	.66	.38	1.04
2,400	.55	.34	.89
2,800	.47	.34	.81
3,200 or more	.41	.32	.73

Source: Fruin and Crnkovich, May 1978.

[a] A $10 million transshipping facility fully amortized over a 20-year period using an 8% interest rate. Property taxes and insurance were estimated at 3% of the capital costs.

final site, Cottage Grove, was selected because it is close to the concentrated industrial areas of the Twin Cities and has been proposed as a potential terminal site.

Ninety-eight demand points were specified throughout central and southern Minnesota. Demand points were selected based on locations of present and potential industrial coal users. At least one demand point was located in each county with existing or potential coal use. The total 1985 coal demand of all consumers was projected to be 4.3 million tons per year.[2] Of this, 2.2 million tons per year was accounted for by "committed" users, i.e., those that are either now using coal or have definite plans to convert. The remaining 2.1 million tons per year is the potential demand if all industrial natural gas customers in the area converted to coal. Initial model runs assumed that all of the potential demand would be realized; this assumption was modified in later runs to allow for situations with less than 100% conversion to coal.

Coal could move to each destination by direct rail shipment from the mine or by being trucked from any of the five terminal locations. All coal was assumed to originate at Colstrip, Montana. Colstrip is the closest western mine and is within a few miles of the route used by virtually all western coal coming to or through Minnesota. The assumption of this particular single mine source will cause total rail costs to be slightly understated, but should have no effect on terminal site selection or transportation mode selection.

The objective of the model was to minimize total transportation and transshipping costs. The objective function was specified as follows:

$$\sum_{1}^{98} a_k X_k + \sum_{1}^{5} b_j Y_j + \sum_{1}^{5} s_j Y_j + \sum_{j=1}^{5} \sum_{k=1}^{98} c_{jk} Z_{jk},$$

where a_k represents the cost of rail shipment per ton directly from the mine to demand points k, $k = 1, \ldots, 98$; b_j is the cost of rail shipment from the mine to transshipping terminal site j, $j = 1, \ldots, 5$; s_j is the per ton transshipping charge at transshipping terminal j; c_{jk} represents the cost of trucking coal from transshipping point j to demand point k; X_k is the amount of coal shipped directly from the mine to the kth demand point; Y_j is the amount of coal which is shipped from the mine to the jth transshipping terminal; and Z_{jk} represents the coal that is shipped from the jth transshipping terminal to the kth demand point. The objective function is subject to the following constraints:

(1) $$\sum_{j=1}^{5} Z_{jk} + X_k \geq D_k, \; k = 1, \ldots, 98,$$

(2) $$\sum_{k=1}^{98} Z_{jk} \leq Y_j, \; j = 1, \ldots, 5,$$

(3) $$X_k \geq 0, \; Y_j \geq 0, \; Z_{jk} \geq 0, \quad k = 1, \ldots, 98, \; j = 1, \ldots, 5,$$

when D_k is the exogenous annual coal demand of the kth demand point.

The rail rates directly from Colstrip to the terminal sites and most final demand points (a_k, b_j) were taken from Fruin and Crnkovich (1978a). Those demand points which were not covered by tariffs were estimated on a per mile basis from existing rates. The amount of coal demanded determined whether single or multiple car rates were used for direct shipments. The truck rates (c_{jk}) used were selected as representative of area truck rates. Rail and highway mileages were taken from the *Rand-McNally Railroad Atlas* and *Highway Mileage Tables*.

Transshipping charges (s_j) were obtained from Fruin and Crnkovich (1978b). Transshipping costs per ton were estimated to decrease as annual throughput increased until an annual volume of 3.2 million tons was reached, after which costs were constant at 73¢ per ton (table 3).

[2] An additional 11.4 million tons per year of the area's projected 1985 coal demand is accounted for by five large power plants. These plants are large enough to receive high volume rail shipments directly from the mines and would not need a new terminal. Therefore, their coal demand was not included in the analysis.

Results of Analysis

The minimum transportation and handling costs and the resulting shipping patterns were obtained, using a linear programming algorithm. The total coal transportation and handling cost of serving all users was first determined under the assumption that no terminals would be constructed. Minimum cost solutions were then obtained, one at a time, assuming a single transshipping facility was constructed and coal could be shipped to each demand point by rail or by truck from the transshipping facility. The initial solution for each terminal was obtained, using the minimum level transshipping cost of 73¢ per ton. The transshipping cost was then increased on successive runs until it corresponded to the volume level going through the terminal. A similar iterative procedure was used with various combinations of the five possible transshipping facilities. The totals of transportation and handling charges for each case were compared to those of the "baseline" case. Results of selected significant cases are reported in table 4.

The least-cost solution was obtained with a combination of the Becker and Cottage Grove sites. Total transportation and handling charges with this solution were 18.9% lower than the $57 million baseline case. For Cottage Grove, the relatively low transshipping charge ($.81/ton) was due to the large amount of coal being transshipped through the terminal (2.8 million tons). In contrast, the low transshipping charge at Becker ($.73/ton) was due to the existing power plant. Even though only 460,000 tons of coal were transshipped to other users from Becker, 3.0 million tons per year are transshipped for use in electrical generation.

The relative importance of the Becker and Cottage Grove sites in the least-cost solution can be seen by comparing that solution with one including only the Cottage Grove site. Although the marginal savings due to adding the Becker site are relatively small, there are significant advantages for using the site as a terminal. The majority of the transshipping facilities are already present because of the power plant. Construction of the additional facilities for the terminal would only cost $2 million. The simple payback period based on the $700,000 savings would be less than three years. Furthermore, truck traffic from the terminals would originate from two sites rather than one, thereby partially alleviating a potentially serious traffic problem.

Because of their distance from the metropolitan area and the dispersion of the remaining demand points, the economic significance of the Granite Falls, Mankato, and Kellogg sites was relatively small and will not be discussed further in this paper.

In each of the above solutions, it was assumed that all committed and potential users would use coal. It is unlikely that all of the potential users will use coal. The high costs involved in converting heating and energy systems to coal, environmental restrictions on coal use in certain areas, and discoveries of new natural gas supplies could all discourage maximum coal conversion. In any case, some potential users would find conversion unprofitable or environmentally impossible and would continue with their present secondary fuel even as the costs for such fuels rise. A mandatory conversion program is the only realistic possibility for achieving the maximum total demand described in the model.

To demonstrate the effect of only some of the users converting to coal, the total demand for each potential user was cut in half. The total reduction in coal demand was only 1.1 million tons, or 25% of the total amount, because the demand by the committed users was not affected. The least-cost solution of the reduced demand model was the same as before, Becker and Cottage Grove. The total savings over the baseline case were, of course, less because less coal was shipped. However, savings of $6.6 million per year were still possible with this case, as compared to savings of $10.8 million per year in the full-demand model. The Becker terminal, which retained the same transshipping charge as before because of the power plant, reduced its

Table 4. Total Shipment and Savings for Selected Transshipping Alternatives

Transshipping Points	Total Shipments	Savings over Baseline	
	(tons)	($)	(%)
None (baseline) Direct from mines	4,297,176	—	—
Becker Direct from mines	2,739,988 1,557,188	6,538,710	11.5
Cottage Grove Direct from mines	3,127,196 1,169,980	10,094,859	17.7
Becker Cottage Grove Direct from mines	460,836 2,812,970 1,023,370	10,796,359	18.9
Becker Kellogg Direct from mines	2,518,261 642,627 1,136,288	7,562,466	13.3

throughput by only 16%, even though overall coal demand was reduced by 25%. In contrast, the Cottage Grove site reduced its throughput amount by 35% because there was no "baseload" demand by a power plant to guarantee a large throughput and low transshipping charges.

Policy Implications

The economic analysis presented here suggests that coal transportation and handling costs could be reduced substantially if new distribution centers were established. The savings to coal users in southern Minnesota were estimated to be $10.8 million per year if all potential coal users convert to coal and $6.6 million per year if the coal demand by potential users is reduced by half.

The present values of these annual savings streams can be used to compare delivered coal price reductions with "up-front" subsidies intended to defray initial conversion costs. The present values were calculated over a twenty-year period, the assumed life of a new terminal, and at rates of 7% and 16%. The 7% rate was chosen as representative of the cost of public money obtained through revenue bonds; the 16% was taken as representative of the cost of capital to small- or medium-sized firms.

At 7%, the present value of the $10.8 million per year savings for twenty years is $114.4 million. The corresponding value for the $6.6 million savings is $69.9 million. At 16%, the two savings streams have present values of $64.0 million and $39.1 million, respectively.

Thus, it can be inferred that even at the lower annual savings rate, private decision makers should find terminal construction to be as attractive as a one-time $39 million subsidy program. For projects using public funds, such as converting public buildings to coal, the savings would be equivalent to a one-time subsidy program of almost $70 million.

Public action to encourage coal terminal development would be far less expensive than equivalent subsidy programs designed to reduce initial conversion costs. The capital costs of terminals could be financed by revenue bonds which would be liquidated by project revenues. Such bonds might require state guarantees, but the total cost to the public would be negligible if the project were successful and relatively small even if the project failed. On the other hand, up-front subsidies would require either tax credits and allowances or outright state or federal grants. Both substantially reduce the tax revenues available for other purposes.

There also would be other advantages to terminal development over up-front subsidies. Terminals would make coal available by truck to potential customers who cannot receive coal by rail, a problem that is not addressed by subsidy programs now being considered. Furthermore, the benefits from reduced coal distribution costs would accrue to all coal users, not just those which are selected for public payments.

In spite of these benefits, it is not suggested here that establishing coal terminals will in and of itself bring about coal conversion. Air quality restrictions on coal use are not addressed. Furthermore, there is no assurance that the savings from terminal use alone will be large enough to make coal conversion attractive for the private sector. For example, consider the case of an installation using 585,000 gallons of residual fuel oil at 31¢ per gallon and facing the coal costs shown in table 2. For approximately $2 million, it could be converted completely to stoker coal firing and use 5,000 tons per year of western coal at $22.81 per ton. If a terminal were available, the cost could be reduced to $19.21 per ton. The simple paybacks for the conversion investment would be thirty years without the terminal and twenty-three years with it. Even though the terminal would save this user $18,000 per year in fuel costs, it is clear that further incentives would be necessary to induce the example industry to convert to coal (Minnesota Energy Agency, p. 41).

It also is pointed out in this paper that the lowest distribution costs for coal would result if the coal-handling equipment at electric generating stations were used for coal distribution as well. The following problems might arise from such an arrangement: (*a*) the possible unwillingness of a railroad to deliver coal bound for several consignees to a central point without raising rates, (*b*) space and other physical limitations at existing generating stations, (*c*) prohibitions on some utilities from engaging in activities other than public utility services, (*d*) difficulty procuring coal, and (*e*) problems caused by increased truck traffic.

The above problems deserve study on a case-by-case basis before any specific proposals are put forth. Problems of physical limitations, coal procurement, and truck traffic would best be addressed by considering proposed generating stations, rather than existing ones, as terminal sites. Therefore, a generating station's potential as a coal distribution center should be considered in future power plant siting decisions.

Summary

A linear transshipment model was used to determine the extent to which delivered coal prices could be reduced through gains in efficiency in coal transportation and distribution. Aggregate savings for coal users in southern Minnesota of as much as $10.8 million per year were shown to be possible.

It was argued that the savings thus obtained would have the same effect as large direct subsidies to potential coal users in encouraging coal use. A program to reduce delivered coal costs would involve less public funding than subsidies in addition to providing coal delivery by truck to industries not able to receive it by rail. Furthermore, the benefits

from reduced coal distribution costs would accrue to all local users, not just those selected for public payments.

The economic savings possible from improved coal distribution and handling, alone, would in many cases be insufficient to encourage coal conversion in the public sector. Further subsidies and consideration of air quality restraints would almost certainly have to be included along with terminal development in an effective program to encourage industrial coal use. However, this in no way detracts from the fact that the savings in coal distribution costs can be achieved at far less public cost than equivalent direct subsidies.

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References

Fruin, Jerry E., and Robert Crnkovich. *Coal Transshipping Costs*. Staff paper draft, Department of Agricultural and Applied Economics, University of Minnesota, May, 1978a.

———. *Western Coal Rates for Minnesota Users*. Staff paper P78-3, Department of Agricultural and Applied Economics, University of Minnesota, Revised April 1978b.

Minnesota Energy Agency. *The Minnesota Coal Study: A Final Report to the Legislature*. St. Paul. September 1978.

Rand-McNally Highway Mileage Tables. Chicago, Ill.

Rand-McNally Railroad Atlas. Chicago, Ill.

Coal Week, 21 Aug. 1978.

Economic Trade-Offs and the North Carolina Shrimp Fishery

James R. Waters, J. E. Easley, Jr., and Leon E. Danielson

The North Carolina shrimp resource consists of three major species, brown (*Penaeus aztecus*), pink (*P. duorarum*), and white (*P. setiferus*). Together, they comprise the state's most important fishery. Two of these species exist in Pamlico Sound, the principal fishing area.

The brown shrimp population represents the primary resource in terms of landings and value received. Members of this species use the many creeks and bays along the North Carolina coast as nursery areas during postlarval stages of development. As individuals mature, they migrate into the deeper waters of Pamlico Sound where they become vulnerable to fishing gear. Fishing activity begins in July and continues until the shrimp migrate to offshore waters, generally in late September or early October, at which time they are lost to the fishery.

The pink shrimp population constitutes the second major shrimp species in North Carolina. These individuals enter Pamlico Sound throughout the summer and utilize the Sound as a nursery area for postlarval growth. Pink shrimp achieve commercial size in October and November. During the winter, pink shrimp remain in Pamlico Sound; surviving adults are harvested in May and June before they migrate to the ocean.

Thus, during August and September, brown and pink shrimp coexist in Pamlico Sound, but at different stages of maturation. Pink shrimp utilize the brown shrimp fishing grounds as a nursery area. As a result, precommercial-size pink shrimp are caught incidentally by fishermen harvesting brown shrimp because the fishing gear does not perfectly discriminate between juvenile and adult shrimp. The juvenile pink shrimp culled from the catch are discarded overboard. Most are killed in the landing, sorting, and discard process.

The purpose of this study is to analyze the incidental catch (or discard) problem to ascertain whether discard abatement policies should be instituted during August and September to protect juvenile pink shrimp. Interest is focused on whether or not the range of observed discard rates is sufficiently large to warrant protection. Because of the lack of required data, the study is primarily a simulation analysis.

Economic Trade-Offs

Since Gordon, Scott, and Clark, the effects of common property resource utilization have been well-known. Fish populations are natural resources that are exploited over time. Communal ownership distorts the choice between present and future income because individual fishermen do not consider foregone future income in their cost calculations.

Harvesting brown shrimp when juvenile pink shrimp are destroyed and discarded in the harvesting process reduces the number of pink shrimp available for capture in the future. This reduction in population size implies a smaller expected number of future shrimp to be landed than would occur if discard did not exist. Therefore, the marginal benefit to be estimated when evaluating a discard abatement policy is the increased value of commercial-size pink shrimp expected to be landed in the late fall, the following spring, and, through spawning, in future years. An additional benefit is the potential reduction in future operating costs. A larger population size would increase population density and may make both locating and harvesting shrimp less time-consuming, and, hence, less costly.

Although reducing the cost of foregone future earnings, policies that protect juvenile pink shrimp will impose other costs on the industry. There are three sources of discard prevention costs to be considered when evaluating a discard abatement policy. The primary cost component is the value of commercial-size shrimp not landed during the discard period that otherwise would have been landed. Second, discard policies may increase vessel operating costs. Fishermen who ignore the presence of the juvenile shrimp enable themselves to land and market shrimp at lower cost. Adopting alternative fishing techniques or more selective gear would mean higher costs of production. Third,

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there may be administrative costs to enforce the policy's regulations. Increased enforcement costs include the expense of employing new enforcement officers and equipment, if needed, and any additional wage payments to existing officers to compensate them for the time required to fulfill their additional duties. Another potential enforcement cost is the increased value of damage that may be inflicted on other species if officers devote relatively less of their time to protecting them from potential violators.

Not all of these potential benefits and costs are included in the analysis, in large part due to lack of data. The most important element in estimating marginal costs and benefits of a discard abatement policy are changes in landings of pink and brown shrimp. Changes in current and future vessel operating costs and enforcement costs are assumed negligible. In addition, fishery biologists consider the environment to be the primary determinant of annual recruitment of shrimp in North Carolina. Hence, the magnitude of this year's catch is assumed to have no impact on next year's catch in the analysis.

The essence of the pink shrimp discard problem is a choice between present and future income. Here, the present is interpreted as the period during which discard occurs. The future is interpreted as the interval during which the benefits of a discard abatement policy will be realized.

The Model

Beverton and Holt advanced the biological model of population change throughout a cohort lifespan. The reduction in population numbers in any instant, τ, is assumed proportional to population size,

$$\frac{dN}{d\tau} = -(M + F)N(\tau). \tag{1}$$

$N(\tau)$ represents population size in numbers, and the coefficients M and F represent instantaneous natural and fishing mortality rates. The natural mortality rate depends on the vulnerability of members to disease, predation, and environmental stress. The fishing mortality rate is a function of the level of fishing activity. Both mortality rates may be assumed constant during short study periods when predator stocks, environmental conditions, and fishing activity are relatively unchanging. McCoy (1968, 1972) and Purvis and McCoy (1974b) have used this model to estimate weekly natural and fishing mortality rates for shrimp in North Carolina.

Integrating (1) yields an expression for the number of individuals remaining in the population and available for capture in each period,

$$N(\tau) = N(\tau_o)e^{-(M+F)(\tau-\tau_o)}. \tag{2}$$

The initial population size, $N(\tau_o)$, is part of the data associated with the problem. Because population size declines exponentially, the maximum age of fish in the fishing ground is predetermined at age T.

$$N(T) = 0. \tag{3}$$

Beverton and Holt adopt the von Bertalanffy weight-age relationship.

$$W(t) = W_{max}[1 - e^{-k(t+a)}]^b. \tag{4}$$

W_{max} represents the maximum weight attained by an average shrimp. The variable a refers to chronological age (in weeks) at time t_o, t denotes weekly intervals, and k and b are parameters. The von Bertalanffy weight equation has been applied on a weekly basis to shrimp in North Carolina (McCoy 1968, 1972; Purvis and McCoy 1974b) and in the Tortugas (Kutkuhn).

The number of shrimp landed, Y, during any week, t, is proportional to average population size during the week, or

$$Y(t) = \int_{\tau=t}^{\tau=t+\Delta t} FN(\tau)d\tau = F\,N(t)\left[\frac{1 - e^{-(F+M)\Delta t}}{M + F}\right], \tag{5}$$

where $\Delta t = 1$ week and $N(t)$ is population size at the beginning of the week. Quantity landed, Q, is simply number landed multiplied by the average weight per shrimp, W.

$$Q(t) = Y(t)W(t). \tag{6}$$

Marginal Benefits

Augmenting the population of pink shrimp at the end of the discard period increases the number of shrimp expected to be landed in the future. Because interest is focused on the increased number of shrimp landed, one can view the number saved from discard as the "initial population size," $N(t_o)$. One can then utilize information about the natural and fishing mortality rates and the weight equation to predict the quantity of these shrimp expected to be landed in each future period.

In documenting the occurrence of juvenile pink shrimp discard, biologists refer to the discard rate, d, defined as the number of juvenile shrimp discarded per commercial-size shrimp landed. The discard rate is used by biologists as their measure of the severity of the discard problem. Policies designed to reduce juvenile pink shrimp discard affect fishermen's incomes by changing the fishing mortality rate and the discard rate during the discard period.[1]

[1] Ordinarily, one would hypothesize alternative policy-induced values for the fishing mortality and discard rates. Then, the number of juvenile pink shrimp saved from discard could be calculated as

$$Number\ Saved = N(t_e) = \sum_{t=t_a}^{t_b} [F_c Z_c d_c N(t_e) e^{-(M+F_c)(t-t_a)} - F_l Z_l d_l N(t_e) e^{-(M+F_l)(t-t_a)}][e^{-(M+F_l)(t_b-t-1)}],$$

The total number of juvenile pink shrimp saved from discard by adopting the ith policy alternative (i.e., the accumulated reduction in juvenile shrimp landings) is approximated as the difference between the number of juvenile shrimp discarded when no specific discard policy applies and when the policy is in effect. The magnitude of this difference depends on the discard rate and the number of commercial-size shrimp landed.

$$(7) \qquad N(t_o) \approx (Q_c A d_c - Q_i A d_i) e^{-M(t_o - t_m)}.$$

The first term represents the number of juvenile pink shrimp that would be discarded if no policy were adopted. The term $Q_c A$ approximates the number of adult shrimp landed. It is the product of the quantity (in pounds) of commercial-size shrimp landed, Q_c, and the average size (number of shrimp per pound) of each marketable shrimp landed. Multiplying by the number of juveniles discarded per adult shrimp landed, d_c, provides an approximation of the number of shrimp discarded.

The second term represents the number of juvenile shrimp expected to be landed incidentally and discarded when the ith policy is enforced. It is the product of the number of marketable shrimp expected to be landed, $Q_i A$, and the discard rate, d_i, that would prevail if the policy were adopted. The difference (7) represents the number of juveniles saved from discard. The factor $e^{-M(t_o - t_m)}$ accounts for those juveniles saved from discard but which die prior to achieving commercial size. Time t_m is taken as the midpoint of the discard period.

Pink shrimp are assumed to be available to the fishery for eight weeks in October and November, and then again in the spring for ten weeks—an assumption approximating observed behavior (Purvis and McCoy 1972). Let V denote the overwintering survival rate. This parameter reflects the percentage of the shrimp population at the end of the fall shrimping season that survive to the first day of the spring season. The overwintering mortality rate must be distinguished from the natural mortality rate, which is an instantaneous decline in population numbers due to natural causes during the fishing season. The overwintering period is assumed to last S weeks. Therefore, the increased quantity of pink shrimp landings due to a discard abatement policy is approximated using

$$(8) \qquad \Delta Q_p = \sum_{t=t_o}^{t_o+8} F_c Z_c W(t)\, N(t_o)\, e^{-(F_c+M)(t-t_o)} + V \sum_{t=n}^{n+10} F_c Z_c W(t-S)\, N(t_o)\, e^{-(F_c+M)(t-S)},$$

where $n = t_o + 8 + S$. The first component represents landings in the fall of pink shrimp saved from discard; the second, those landings in the spring after overwintering. During the overwintering period, pink shrimp do not grow, hence the use of $W(t - S)$ in the second component of equation (8). Time t_o represents the instant at which the discard policy ceases to be in effect.

The value of the increased future landings is the product of the discounted price per pound, $P(t)$ $R(t)$, corresponding to the average-size shrimp and the increased quantity landed during each week.[2] Price is a function of shrimp weight and seasonal factors. The larger the shrimp, the higher the price per pound. Unlike in other states, there is no market price differentiation by species. $R(t)$ is a discount factor of the form $(1 + r)^{-(t+g)}$, where g is the length of the discard period.

In summary, the benefit of a discard abatement policy is approximated using (9).

$$(9) \qquad B = \sum_{t=t_o}^{t_o+8} P(t)R(t)\, F_c Z_c\, W(t)\, N(t_o)\, e^{-(M+F)(t-t_o)} + V \sum_{t=n}^{n+10} P(t)R(t)\, F_c Z_c W(t-S)\, N(t_o)\, e^{-(M+F_c)(t-S)}.$$

The summations here represent discounted values of future shrimp landed in the fall and later in the

where

$$Z_c = \left(\frac{1}{M+F_c}\right)[1 - e^{-(M+F_c)}],$$

$$\text{and } z_i = \left(\frac{1}{M+F_i)}\right)(1 - e^{-(M+F_i)}).$$

The first term represents the number saved during each week within the discard period, $t_a \le t \le t_b$. The second term records the number saved which survive until the end of the discard period. $N(t_a)$ denotes the number of brown shrimp in the fishing area at the beginning of the discard period. The c subscript denotes the current levels of F and d while the i subscript denotes policy-induced values. However, due to the lack of information concerning the magnitude of $N(t_a)$, an alternative method of enumerating the number of juveniles saved from discard was devised.

[2] Annual North Carolina shrimp landings constitute a small proportion of the U.S. total, usually between 2% and 4%. The share is higher during the peak North Carolina landings months of July through September. In testing the effects of North Carolina landings on North Carolina prices, monthly observations were employed for the years 1969–75. Price equations were estimated for different size classes, with few coefficients being significant (hence, North Carolina prices follow those established in the larger Gulf or national market). The North Carolina quantity coefficient was significant, however, for size class 41–50 per pound, the dominant size in North Carolina landings. This equation was estimated in the following form, with t-values shown in parentheses (***, .001; **, .01, *, .05):

$$\ln P_t = -3.43842 - \underset{(-3.43^{**})}{.00015Q_t} - \underset{(-4.87^{***})}{.00779S_{t-1}} + \underset{(2.33^{*})}{.00904Y_t} - \underset{(-2.26^{**})}{.01168Z_t} + \underset{(3.21^{**})}{.01203B_t} - \underset{(-0.41)}{.00129F_t},\ R^2 = .75,$$

where P is ex-vessel price for size 41–50 in North Carolina, deflated by the CPI ($/lb.); Q, total landings, all sizes, in North Carolina (1000 lbs.); S, U.S. inventory of shrimp in cold storage (million lbs.); Y, per capita U.S. income, deflated by the CPI ($/person); Z, shrimp landings in other Southeastern and Gulf States (million lbs.); B, consumer price index for beef products; F, consumer price index for food fish. The price flexibility is evaluated, at the mean of each variable, as −.03. Hence, there is some support for assuming the demand for shrimp in North Carolina is perfectly elastic.

spring. As noted before, the effects of discard policies on vessel operating costs, enforcement costs, and landings in future years are assumed negligible. Further, the possibility of increased brown shrimp landings in October and November is ruled out because brown shrimp virtually complete their migration from Pamlico Sound and out of the fishing area by the end of the discard period (McCoy 1968). Finally, note that benefits are estimated by calculating the impact on aggregate fishery income. It should be recognized that incomes of individual fishermen could be affected differently by a policy's restrictions on fishing activity.

Marginal Costs

The primary cost component of a discard abatement policy is the value of commercial-size shrimp not landed during the discard period that otherwise would have been landed. A management policy reduces the fishing mortality rate, and hence the number of adult and juvenile shrimp landed in each time interval, by changing one or more components in the production function (for example, the minimum legal mesh size). The accumulated reduction in commercial-size shrimp landings throughout the discard period is approximated as the difference[3]

$$\Delta Q_b \approx (Q_c - Q_i) \cong Q_c(1 - x), \tag{10}$$

where Q_c denotes landings that would occur if no policy were implemented, Q_i represents the quantity of brown shrimp that would be landed if the *i*th policy were adopted, and the expression $(1 - x)$ is an assumed percentage reduction in brown shrimp landings. The value of this reduction is simply $P\Delta Q_b$, because demand is perfectly elastic where P is the observed average price during the discard period.

The reduction in current income due to harvesting fewer juvenile pink shrimp is evaluated as zero because there is no market price for juveniles. As indicated earlier the effects of discard policies on vessel operating costs and enforcement costs are considered negligible.

[3] The total policy-induced reduction in shrimp landings is the accumulated reduction from each of the time intervals while the discard policy is in effect, or,

$$\Delta Q_b = \sum_{t=t_a}^{t_b} [F_c Z_c N(t_a) e^{-(M+F_c)(t-t_a)} - F_i Z_i N(t_a) e^{-(M+F_i)(t-t_a)}] W(t) [e^{-(M+F_i)(t_b-t-1)}].$$

At present, there is no information about the magnitude of brown shrimp population, $N(t_a)$, hence the use of an approximation.

Break-Even Discard Rate

To determine whether unregulated discard rates are "too high," an expression for the break-even discard rate, d_e, is derived. The break-even rate is interpreted as that discard rate for which marginal benefits just equal marginal costs of achieving it. If observed discard rates exceed the break-even rate, the benefits of protecting juvenile pink shrimp exceed the costs. Observed rates less than the break-even rate imply that discard abatement costs exceed expected benefits.

Let the policy-induced discard rate be proportional to the unregulated rate,

$$d_i = v\, d_c. \tag{11}$$

Thus, for a discard abatement policy that reduces the discard rate by 70%, $v = 0.3$. To determine the break-even rate, substitute (11) into (7), and (7) into (9), and solve for $d_c = d_e$. We have

$$d_e = \frac{P(Q_o - Q_i)}{G}, \tag{12}$$

where

$$G = \sum_{t=t_0}^{t_0+8} P(t)R(t)\, F_c Z_c\, W(t)(Q_c A - Q_i A) e^{-(M+F_c)(t-t_0)} + V \sum_{t=n}^{n+10} P(t)R(t)\, F_c Z_c\, W(t - S)(Q_c A - Q_i\, A) e^{-(M+F_c)(t-S)}.$$

Application

Several management policies have been suggested as a means of reducing pink shrimp discard. The first ($i = 1$) is a policy of closing the fishery during the period when discard is likely to occur. Closing Pamlico Sound completely eliminates the discard problem, $d_1 = 0$. However, it also entails the highest cost in terms of sacrificed brown shrimp landings, since $Q_1 = 0$.

The second proposal ($i = 2$) is to prohibit shrimping at night when pink shrimp discard occurs. Brown shrimp can be either nocturnal or diurnal, while pink shrimp are nocturnal. Prohibiting night shrimping would virtually eliminate the discard problem except at sunrise and sunset, when members of both species are active. However, if brown shrimp primarily feed at night, this policy would virtually eliminate brown shrimp landings as well as the pink shrimp discard.

In simulating the effects of these two policies, the parameter values shown in table 1 were used. Hypothesized values for the unregulated weekly fishing and natural mortality rates fall within the range of values estimated by McCoy (1968, 1972) and Purvis and McCoy (1974b). Average sizes for juvenile pink shrimp were observed by Purvis and

Table 1. Alternative Parameter Values Used in Simulations

Brown Shrimp Landings Reduced (%)	Discard Rate Reduced (%)	Fishing Mortality Rate	Natural Mortality Rate	Over-wintering Survival (%)	Average Size Number/Pound	
					Brown	Pink
100	100	.20	.25	75	21–25	90
85	75	.15	.20	50	26–30	125
70	50				31–35	
50	25					
25						

Note: Various combinations of values in each column were used.

McCoy (1974a) and Purvis et al. (1977). The discount rate is assumed to be 1% per month or approximately 0.25% per week. Prices used in the analysis were those observed in the 1975–76 season; hence, price changes due to weight increases and seasonal variation are incorporated. Pink shrimp weight in each future period was calculated from the equations estimated by McCoy (1972). No information is available about the proportion of shrimp that successfully overwinter from the fall to the spring season. The simulations presented here assume a 50% survival rate. Increasing the overwintering survival rate from 50% to 75% did not appreciably change the calculated break-even rate. Apparently, the bulk of the benefits of protecting juvenile pink shrimp will be realized before the overwintering period.

Table 2 summarizes the results for the selected situations described in table 1. Each row pertains to a different percentage of reduction in the discard rate. Each column refers to the percent change in brown shrimp landings. Tabled values represent calculated break-even discard rates. Only one entry exists in the first row and column because it is impossible to eliminate completely the entire juvenile shrimp catch without closing the fishery. Situations using other parameter values were examined but are not presented here. Some earlier estimates are contained in Waters, Danielson, and Easley.

Inspection of table 2 reveals that very few of the hypothesized situations generated break-even discard rates as low as 5.0 juveniles discarded per commercial-size shrimp landed. On the other hand, more than 50% of the hypothesized situations implied break-even rates of 10.0 or greater. The calculated break-even rate (including those results not presented here) ranged from approximately 3.5 to 26.3.

Implications for Fishery Management

Table 3 summarizes the results of efforts to document the incidental catch and discard of juvenile pink shrimp. All information was gathered by sampling different shrimping areas with standard fishing gear. Column (3) represents the observed number of juvenile pink shrimp discarded per commercial-size shrimp harvested. Columns (4) and (5) show the average shrimp size by species. Column (5) sometimes includes an average size greater than the minimum commercial size of seventy per pound because not all pink shrimp landed were pre-commercial-size.

Table 3 suggests that discard rates are seldom observed to be as high as 3:1. Although observed discard rates appear small, a rate of 1:1 implies that 50% of all shrimp landed (by number) are discarded. In addition, the pink shrimp vulnerable to being incidentally landed and discarded often grade smaller than ninety per pound. A comparison of tables 2 and 3 reveals that, in general, observed discard rates are less than the computed break-even rates. Hence, marginal costs exceed marginal benefits of protecting juvenile pink shrimp in most

Table 2. Break-Even Discard Rates

Policy	Percent Decline of Discard Rate	Percent Decline of Brown Shrimp Landings: 100	85	70	50	25
1. Close fishery	100	16.3	—	—	—	—
2. Prohibit night shrimping	75	—	14.4	12.4	9.3	5.0
	50	—	15.0	13.4	10.9	6.5
	25	—	15.6	14.7	13.1	9.3

Note: $M = 0.25$, $F = 0.20$, $V = 0.50$; average brown shrimp size is 26–30, average pink shrimp size is 90.

Table 3. Pink-Brown Shrimp Discard Data, Pamlico Sound and Core Sound

Date (1)	Location (2)	Discard Ratio: Number of Juvenile Shrimp / Number of Adult Shrimp (3)	Average Size of Brown Shrimp (number per pound) (4)	Average Size of Pink Shrimp (number per pound) (5)
8-21-70	Pamlico Sound	.39:1	29	107
8-27-70	Pamlico Sound	1.93:1	23	109
10-19-70	Pamlico Sound	no brown shrimp	no brown shrimp	61
9-7-71	Pamlico Sound	.69:1	30	106
9-16-71	Pamlico Sound	1.34:1	28	90
8-26-75	Pamlico Sound	9.64:1	31	222
9-3-75	Pamlico Sound	.69:1	28	113
9-17-75	Pamlico Sound	.27:1	28	71
9-30-75	Pamlico Sound	.68:1	28	75
10-4-75	Pamlico Sound	.35:1	31	67
10-28-75	Pamlico Sound	.07:1	35	44
9-17-71	Core Sound	2.88:1	37	93
10-12-71	Core Sound	no brown shrimp	no brown shrimp	78

Source: Purvis and McCoy (1974a); Purvis et al. (1977).

instances. It does not appear that the incidental catch and discard phenomenon is severe enough under normal conditions to warrant the adoption of policies designed to protect juvenile pink shrimp. However, exceptional situations may arise. Table 3 indicates that, in one case, 9.6 juvenile pink shrimp were discarded for every commercial-size shrimp landed. Hence, biologists may want to continue monitoring the discard phenomenon.

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References

Beverton, Raymond, and Sidney J. Holt. *On the Dynamics of Exploited Fish Populations*. London: Ministry of Agriculture, Fisheries and Food, Her Majesty's Stationery Office. Fishery Investigations, Ser. 2, vol. 19, 1957.

Clark, Colin W. "The Economics of Overexploitation." *Science* 181(1973):630–34.

Gordon, H. S. "Economic Theory of a Common Property Resource: The Fishery." *J. Polit. Econ.* 62(1954): 124–42.

Kutkuhn, Joseph H. "Dynamics of a Penaeid Shrimp Population and Management Implications." *Fishery Bulletin* 65(1966):313–38.

McCoy, Edward G. *Dynamics of North Carolina Commercial Shrimp Populations*. Spec. Sci. Rep. No. 21, Division of Commercial and Sports Fisheries, North Carolina Dep. Nat. and Econ. Resour., Raleigh, 1972.

———. *Migration, Growth and Mortality of North Carolina Pink and Brown Penaeid Shrimps.* Spec. Sci. Rep. No. 15, Division of Commercial and Sports Fisheries, North Carolina Dep. Conserv. and Develop., Raleigh, 1968.

Purvis, Connell, and Edward G. McCoy. *Overwintering Pink Shrimp, PENAEUS DUORARUM, in Core and Pamlico Sounds, N. C.* Spec. Sci. Rep. No. 22, Division of Commercial and Sports Fisheries, North Carolina Dep. Nat. and Econ. Resour., Raleigh, 1972.

———. *Pink-Brown-Shrimp Discard Studies in the Core-Pamlico Sound Area.* Spec. Sci. Rep. No. 26, Division of Commercial and Sports Fisheries, North Carolina Dep. Nat. and Econ. Resour., Raleigh, 1974a.

———. *Population Dynamics of Brown Shrimp in Pamlico Sound.* Spec. Sci. Rep. No. 25, Division of Commercial and Sports Fisheries, North Carolina Dep. Nat. and Econ. Resour., Raleigh, 1974b.

Purvis, Connell E., James R. Waters, Leon E. Danielson, and J. E. Easley, Jr. *Bioeconomic Evaluation of Mixed Penaeid Shrimp in Pamlico Sound.* Unpublished completion report for State-Federal Fisheries Management Program Contract No. 03-5-042-26, North Carolina Dep. Nat. and Econ. Resour., Div. Marine Fisheries, Morehead City, 10 June 1977.

Scott, Anthony. "The Fishery: The Objectives of Sole Ownership." *J. Polit. Econ.* 63(1955):116–24.

Waters, James R., Leon E. Danielson, and J. E. Easley, Jr. *An Economic Analysis of the Shrimp Discard Problem in Pamlico Sound.* Econ. Res. Rep. No. 40, Dep. Econ. and Business, North Carolina State University, Feb. 1979.

Transfer of Development Rights: A Market Analysis

Leslie E. Small and Donn A. Derr

Increasing concern about the quality of life in urbanizing areas and the impact of urbanization both on environmentally sensitive areas and on the land resource base for agriculture has led some state and local governments to consider policies designed to alter market forces affecting private land use decisions in ways that foster retention of open space. Among these policies is a series of related proposals known as the transfer of development rights (TDR), the generic feature of which is the provision for an increase in the density of urban development in some areas in exchange for the permanent retention of open space in other areas.

The type of TDR program analyzed here provides for a designated open space or "preservation" zone in which urban development is prohibited. As compensation for the resultant reduction in the current market value of their land, owners of land in this zone are issued certificates of development rights (DRCs) which can be sold to any willing buyer. A receiving zone in which these DRCs can be utilized is also delineated. Residential development without the utilization of DRCs is permitted in this receiving zone, but only up to the density limit authorized by the basic zoning ordinance; development to a higher "bonus" density limit requires the utilization of DRCs.

Critical to the implementation of such a TDR program is the compensation issue: there must be a reasonable possibility that owners of land in the open space zone can sell their DRCs at a price which represents some acceptable level of compensation. The determination of that level is a normative issue which will not be dealt with here. Rather, this note examines the nature of the demand for DRCs under a TDR program based on residential development and discusses the relationship between the design of TDR and its potential to provide compensation. The resulting analytical approach is then applied to a case study community in New Jersey.

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The Demand for DRCs

Decisions regarding the utilization of DRCs would be made by individual developers selecting the optimum density at which to develop. If lot size is a positively valued good for an important segment of the market, then as density increases, the market price of houses of exactly the same physical construction would decrease. Cost per housing unit would decrease because of reductions in the costs of site development (shorter streets, sidewalks, water and sewer lines, etc.) and raw land. Furthermore, developers typically build smaller houses at higher densities, resulting in additional decreases in both revenues and costs. Although various approaches to the analysis of the demand for DRCs have been taken in the literature (Bailey and Ogg, Berry and Steiker, Ervin et al., Field and Conrad), none of them provides for both revenue and cost per housing unit to decline as density increases. They all attempt to analyze the demand for DRCs while either abstracting from, or holding constant, housing quality. But the demand for DRCs depends on the densities at which development occurs, and density is one component of housing quality. This section presents a model which incorporates this relationship between density and housing quality.

The demand model for DRCs is for a single locality within a larger metropolitan area. One basic limiting assumption is that the area in which the TDR program is implemented represents such a small proportion of the total new housing market in a given metropolitan region that housing prices would not be affected by TDR (Berry and Steiker). The cost of DRCs could not, therefore, be passed on to the ultimate consumers of housing. This assumption appears realistic in current situations where TDR might be introduced in only a few locations within a metropolitan area. A second assumption is that zoning ordinances of the minor civil divisions making up the metropolitan area effectively limit residential development to densities below the "bonus" densities permitted under TDR. If this were not the case, the establishment of a "bonus" density by a community implementing TDR could fail to create the desired demand for DRCs, because developers could build at the same density in nearby non-TDR communities.

It is assumed that decisions concerning the utilization of DRCs are made by the relatively small number of competing, profit-maximizing developer-builders who operate in a given community. For each developer, the marginal cost of pro-

ducing housing units at any given density is assumed to be constant until his capacity constraint is reached, at which point the marginal cost becomes greater than the price. This capacity constraint is assumed to be related to the number of housing units constructed, and is independent of the density at which development occurs. For simplicity, we assume that a given developer builds at only one density in a given period. Furthermore, we assume that individual developers expect that their entire production of housing in a given period can be sold at a constant price, although their estimate of that price would be tempered by their knowledge of the amount of housing built in the previous period, and of the planned activities of other developers in the current period.

Production of housing generates a "surplus" defined as the difference between the sale price of the house and all nonland costs (including a competitive return to the developer's capital and managerial abilities). Under perfectly competitive conditions among developers, this entire surplus could be expected to accrue to the owners of land. But in situations where there are continual changes in the housing market and where competition among developers is somewhat limited due to factors which restrict entry (such as capital requirements and transactions costs associated with undertaking activity in a new municipality), a portion of this surplus would accrue to developers. This portion—the difference between the surplus generated by a housing unit and the cost of the raw land needed for that unit—is termed the "residual profit."

In competitive equilibrium, the residual profit should be equal for all densities of housing. In reality, this competitive equilibrium position is seldom likely to exist. Many factors—zoning restrictions, changes in preferences, errors by developers in anticipating market demand (leading to temporary over-building of certain housing types), changes in credit availability (causing the mix of market participants to change), and others—are likely to cause the residual profit to vary among densities at any given point in time. A developer attempting to maximize his net income in a given period would select the density with the greatest residual profit per housing unit.

With TDR, sellers of DRCs would capture some of this residual profit. The maximum amount a developer could afford to pay for the DRCs necessary to build one unit of housing would be the residual profit generated by that unit. But, because he could produce low-density housing (for which no DRCs are required) and capture the entire residual profit, the maximum amount that a developer would be willing to pay for DRCs would be equal to the increase in the residual profit resulting from building at the higher density. The quantity of DRCs demanded by an individual developer in a given time period would depend on the residual profits of housing at different densities, the DRC requirements per housing unit at different densities, and the price of DRCs.

Demand and the Design of TDR

Regardless of the level of compensation provided under TDR, equity among landowners in the open space zone requires that DRCs be distributed in proportion to the estimated reduction in the market value of their land (Ervin et al., Small). This has the effect of defining DRCs in terms of dollars of reduced market value. Let one DRC represent one dollar of reduced land value, and let k represent the desired or acceptable level of compensation expressed as a proportion of the total reduction in land value. In the aggregate, the DRC market could provide the specified level of compensation only if it had the potential to sustain an initial DRC price equal to k, which could therefore be called initial compensation price. This condition does not imply, however, that the actual initial price will be k, since it is not possible to know in advance the actual performance of a private market. The significance of k as the initial compensation price is that at this price, an individual landowner could sell his DRCs immediately upon the implementation of TDR and receive the acceptable level of compensation.

Subsequent to their creation, DRCs are a storable good in fixed supply with no inherent utility in ownership. Regardless of whether they are held by the owners of open space, developers, or speculators, equilibrium in the DRC market therefore requires that the expected DRC price rise over time at a rate equal to the cost of holding DRCs. This would include the opportunity cost of capital, risk, and DRC taxes. Given the initial compensation price (k) and the cost of holding DRCs, the compensation price for DRCs at any point in time is determined.

For developers to be willing to purchase DRCs at any point in time, the DRC price multiplied by the DRC requirement per housing unit must be no more than the increase in residual profit resulting from building at the bonus density. In particular, this condition must hold in the last year in which DRCs are utilized. Thus, the compensation price in that last year (which is determined by k, the cost of holding DRCs, and the length of time over which the DRCs are utilized) determines the maximum DRC requirement per housing unit which is consistent with the desired level of compensation.

Unless there is provision for periodic increases in the required number of DRCs per housing unit, this maximum DRC requirement must apply throughout the life of the TDR program. The longer the expected length of time between the creation of DRCs and the utilization of the last DRC, the lower will be the maximum DRC requirement per housing unit, but the larger will be the number of housing units utilizing DRCs. As this length of time increases, *ceteris paribus*, the maximum number of DRCs utilized during the life of the TDR program first

increases and then decreases. Assuming a constant number of new housing units per year, the maximum number of DRCs demanded occurs for programs designed for the utilization of all DRCs within a fifteen-year period if the holding costs are 7%, and within a ten-year period if the holding costs are 10%.

It is, thus, possible to identify six key factors in the design of TDR: (*a*) the cost of holding DRCs, (*b*) the expected length of time over which DRCs are to be utilized, (*c*) the desired level of compensation (k), (*d*) the expected increase in residual profit, (*e*) the expected rate of housing construction at the bonus density, and (*f*) the average reduction in land values per acre in the open space zone. Given the cost of holding DRCs, the TDR program should be designed for a period of DRC utilization no longer than would result in the maximum utilization of DRCs. Once this planned period of DRC utilization has been established, knowledge of the desired level of compensation and of the expected increase in residual profit can be used to establish the DRC requirement per housing unit. This, together with the estimated number of housing units to be built at the bonus density during the period of DRC utilization, gives the estimated total number of DRCs utilized. This should be no greater than the number of DRCs created, which, by definition, equals the initial reduction in market value in the open space zone. Given the average reduction in land values per acre, the acreage of open space that can be supported by the TDR program at the desired level of compensation can then be determined.

Analysis of a Case Study

To gain insight into the potential and limitations of TDR, a case study for the Township of South Brunswick, located in Middlesex County, New Jersey, was undertaken. A proposed TDR ordinance (which has not been implemented) was developed (Nieswand et al.), followed by an examination of the market aspects of the ordinance, in which the conceptual approach discussed above was applied to the specifics of the case situation (Small et al.).

South Brunswick's location in the Boston-Washington corridor, about midway between New York City and Philadelphia, contributed to a rapid rate of growth since 1950. Since 1960, its population has grown at about 3.1% per year. With a current population of about 18,000 people, the township has a population density of about 435 people per square mile. About 11,300 acres—43% of the land in the township—is devoted to agricultural production. Another 8% of the land is classified as vacant. There is interest in retaining the land base necessary for a viable agriculture, as well as protecting the underground water supply of the township by limiting development on important aquifer-recharge areas. All of the township is zoned, and urban development has been in close conformance to the densities permitted by the zoning ordinance.

The TDR proposal for South Brunswick called for an open space zone of approximately 6,700 acres and receiving zones of 1,900 acres. Based on the current zoning of the open space zone (agricultural/residential with maximum gross densities ranging from 0.32 to 1.3 housing units per acre), approximately 4,200 potential housing units would be eliminated. The current zoning of the receiving zones (agricultural/residential with maximum gross densities ranging from 0.32 to 1.8 housing units per acre) would permit approximately 2,000 new housing units. With the use of DRCs, maximum densities could rise to between 3.0 and 5.0 housing units per gross acre, increasing by 6,700 the number of potential new housing units in the receiving zones. The net effect of the TDR ordinance would thus be an increase of about 2,500 in the number of new housing units permitted in the township. In addition to the 8,600 acres in the open space and receiving zones, there are 5,400 acres of residentially zoned land (including more than 500 acres on which townhouses and garden apartments are permitted) for which the zoning would remain unchanged.

Determining the magnitudes of five of the six items of information needed to evaluate the South Brunswick TDR proposal presented no difficulties. The real cost of holding DRCs was estimated to be from 7% to 10%. This included 2% for DRC taxes, 2% to 3% for an inflation-free return to a low-risk investment; and 3% to 5% as a return to the risk of holding DRCs. The expected length of time of DRC utilization was chosen to maximize the demand for DRCs. This period—which depends on the cost of holding DRCs—ranged from 15 to 10 years. In the absence of any clear agreement on the acceptable level of compensation, alternative values of k, between zero and one, were considered. Past rates of population growth and housing construction along with alternative estimates of future population growth and household size were evaluated to develop three alternative rates of total housing construction: 75, 150, and 250 units per year. It was assumed that three-fourths of these units would be built at the bonus density. Based on information generated in the development of the TDR proposal (Nieswand et al., pp. 73–75, 89) and on agricultural use-value appraisals conducted in Burlington County, New Jersey, as part of a pilot project for the purchase of development rights by the state government, alternative estimates of the average reduction in the market value per acre in the open space zone of $3,150 and $2,500 were developed.

Much of the analysis was devoted to estimating the one remaining factor, the increase in residual profits that could be expected in South Brunswick. Three types of housing at densities which large-scale developers could expect as options in South Brunswick were selected: single-family detached housing, at six densities ranging from 1.3 to 5.0

houses per gross acre; townhouses (single-family attached units) at three densities from 6 to 10 units per acre; and two-story garden apartments at four densities from 10 to 18 units per acre. For each density selected, the specific type and size of the housing unit were chosen on the basis of a market survey of new housing developments.

An estimate of the residual profit for each of the thirteen housing type and density combinations was developed from estimates of total costs and revenues. A hypothetical subdivision layout was prepared for each of the thirteen alternatives. To incorporate the economies of size associated with tract developments, each layout contained approximately 180 units. The arrangement of the dwelling units at the various densities was held as nearly constant as possible. The physical requirements for the components of site development and housing construction were determined from the layouts, using the requirements of South Brunswick's ordinances.

Some of the site development costs were estimated on the basis of information provided by the New Jersey Builders' Association, landscape contractors, and officials of utility companies. The remaining site development costs and the costs of the structures were estimated by Wood and Tower, Inc., of Princeton, New Jersey, a firm that specializes in construction cost estimation. Municipal fees were based on the fee schedules of South Brunswick. Estimates of the finance costs and of the market value of the capital, management, and labor provided by the developer were made on the basis of information gathered from individuals involved in real estate finance. Data on recent transfers of land in South Brunswick were evaluated to provide information on the cost of raw land.

Estimates of the potential revenue for the single-family and townhouse subdivisions were made on the basis of information gathered on current sales of new housing in South Brunswick and surrounding areas and from interviews with real estate brokers. Estimates of the potential revenue for the garden apartment subdivisions were made on the basis of a gross rent multiplier, which converted the effective annual contractual rent into an estimate of market value.

Results

The results of the investigation into the market conditions for South Brunswick are presented in table 1. The residual profits in column 7 indicate the relative attractiveness to developers of alternative housing types and densities under the market conditions prevailing in South Brunswick during the first six months of 1977, and are estimates of the maximum amounts that developers could afford to pay for DRCs. The figures indicate that low-density, single-family detached housing is the most attractive to developers, with a residual profit of about $4,700 per housing unit. The estimated residual profit falls to about $2,300 per unit for the high-density, single-family housing types, and to $1,000 per unit for the low-density townhouses. Higher density townhouses and garden apartments appear unprofitable. These results are consistent with activity in the housing market in South Brunswick,

Table 1. Estimated Market Value, Costs, and Residual Profit per Housing Unit by Housing Type and Density, South Brunswick Township, New Jersey, January–June 1977

Housing Type and Density	Market Value (1)	Land Cost[a] (2)	Site Improvement Cost (3)	Structure Cost (4)	Overhead and Profit Cost (5)	Total Cost (6)	Residual Profit (7)
	($/housing unit)						
Single family detached							
1.3	71,900	3,800	9,200	49,700	4,400	67,100	4,800
1.8	69,700	2,800	8,200	49,700	4,300	65,000	4,700
3.0	62,000	1,700	6,400	46,500	4,000	58,600	3,400
3.4	60,000	1,500	5,900	46,500	3,900	57,800	2,200
4.0	55,300	1,300	5,400	42,700	3,600	53,000	2,300
5.0	40,700	1,000	5,000	29,800	2,600	38,400	2,300
Townhouse							
6.0	46,200	800	3,700	37,600	3,100	45,200	1,000
8.0	42,000	600	3,500	36,100	3,000	43,200	−1,200
10.0	40,000	500	3,200	35,000	2,800	41,500	−1,500
Garden apartment							
10.0	28,200	500	2,900	26,400	2,200	32,000	−3,800
12.0	24,900	400	2,700	20,700	1,800	25,600	− 700
16.0	23,500	300	2,300	19,600	1,700	23,900	− 400
18.0	23,500	300	2,200	19,600	1,700	23,800	− 300

[a] Based on raw land price of $5,000 per acre.

which has been limited largely to low density single-family houses. Concern over rent control and the need for increased contractual rent to cover rapidly rising construction costs has adversely affected investor demand for apartments.

These results suggest that at the time of the study, the TDR program would have failed to generate any significant demand for DRCs. The results, however, are highly sensitive to changes in the housing market. The $2,500 difference in the residual profit between the most profitable density (1.3 units per acre) and the highest density of single-family detached houses could be eliminated by either a 3.5% reduction in the price of the dwelling at 1.3 units per acre, or an increase of 6.1% in the price of houses built at 5.0 units per acre. Given the volatility of the housing market, substantial changes in the relationship among the residual profits at various densities might take place during a relatively short time span, resulting in a highly unstable demand for DRCs.

Assuming that changing market conditions might lead to a structure of residual profits favorable to high-density, single-family detached housing, the results of the housing market study provide some insight into the range of values likely for the increase in residual profits. The residual profits estimated for the single-family detached houses range up to $4,800 per house, with the largest difference between any two single-family densities being $2,600. These figures suggest that under market conditions in South Brunswick favorable to TDR, the increase in residual profit from building at the bonus density is not likely to exceed $5,000. An increase on the order of $1,000 to $3,000 per housing unit would appear more realistic.

Based largely on physical criteria, an open space zone of 6,700 acres was proposed for South Brunswick. Using the most favorable estimate of the cost of holding DRCs (7%), of the rate of construction of new housing (250 units per year, three-fourths of which are assumed to be built at the bonus density), of the increase in residual profit per unit ($5,000), and of the reduction in land value in the open space zone ($2,500 per acre), an open space zone of 6,700 acres implies a value of k of 0.30. Alternatively, using the same assumptions listed above, the maximum size of the open space zone would be 4,077 acres if k is 0.5, and 2,039 acres if k is 1.0. If the rate of housing construction is assumed to be at the moderate level of 150 units per year, of which three-fourths are at the bonus density, the open space that could be retained by TDR would be 2,446 acres if k is 0.5 and 1,233 acres if k is 1.0. Under these assumptions, an open space zone of 6,700 acres would imply a value of k, of 0.18. Thus, even with favorable market conditions, severe constraints exist either on the amount of open space that could be retained or on the level of compensation that could be expected.

Conclusions and Implications

The basic presumption underlying virtually all TDR proposals—that high densities are more attractive to developers than low densities—needs careful empirical investigation in any given situation where TDR is being proposed. The market investigation for the South Brunswick case study led to the conclusion that high density was less attractive than low density at the time of the study.

The amount of open space that can be supported by a TDR program depends on the reduction in land values in the open space zone, the proportion of that reduction deemed acceptable as compensation, the cost of holding DRCs, the expected length of time over which DRCs are to be utilized, the increase in residual profit at the bonus densities, and the rate at which new houses are built at these densities. The analysis of the case study suggests that the economics of the housing and land markets may place severe constraints on the amount of open space that a TDR program can support unless low levels of compensation are accepted.

Consideration of the above factors can lead to the design of a TDR program that has the potential to maintain an average price level consistent with the desired degree of compensation. It does not, however, guarantee either that the aggregate level of compensation forthcoming will be equal to the desired level or that each individual participant in the market will receive the desired level of compensation. Implicit in the reliance on a private DRC market is acceptance of the fact that some sellers of DRCs will gain by selling when prices are favorable, while others will sell during periods of depressed prices. Such occurrences are especially likely in view of the probable volatility of the DRC market.

Finally, there is no reason to expect that the amount of open space that a TDR program could support would be socially optimal. Under TDR, the cost of the open space is paid for from the increases in the residual profits of developers. These increases are not a function of the benefits of the open space, but rather are a function of the restrictions on density which exist in the original zoning, and on the demand for higher density housing. Thus, even private costs and benefits of open space would not be equated by TDR. But even if they were, the amount of open space which TDR could support would be less than the socially optimal amount, due to the fact that many of the benefits of open space have characteristics of public goods, and would thus be external to the participants in the DRC market.

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References

Bailey, Mark R., and Clayton W. Ogg. "Transfer of Development Rights: An Analysis of a New Land Use Policy Tool: Comment." *Amer. J. Agr. Econ.* 59(1977):391–93.

Berry, David, and Gene Steiker. "An Economic Analysis of Transfer of Development Rights." *Nat. Resourc. J.* 17(1977):55–80.

Ervin, David E., James B. Fitch, R. Kenneth Goodwin, W. Bruce Shepard, and Herbert H. Stoevener. *Land Use Control: Evaluating Economic and Political Effects*. Cambridge, Mass.: Ballinger Publishing Co., 1977.

Field, Barry C., and Jon M. Conrad. "Economic Issues in Programs of Transferable Development Rights." *Land Econ.* 51(1975):331–40.

Nieswand, George H., B. Budd Chavooshian, Thomas Norman, and Michael Bolan. *Transfer of Development Rights: A Demonstration*. New Jersey Coop. Extens. Serv. Bull. No. 419, Rutgers University, 1976.

Small, Leslie E. "Transfer of Development Rights: An Analysis of a New Land Use Policy Tool: Comment." *Amer. J. Agr. Econ.* 58(1976):761–62.

Small, Leslie E., Victor Kasper, Jr., and Donn A. Derr. *Transfer of Development Rights: Marketability*. New Jersey Agr. Exp. Sta. Bull. No. 848, Rutgers University, 1978.

Recreation Demand Equations: Functional Form and Consumer Surplus

Rod F. Ziemer, Wesley N. Musser, and R. Carter Hill

The subject of recreation demand has increasingly attracted the attention of economic research. The demand equations resulting from this research follow the Hotelling-Clawson model of recreation demand, in which occasions (or days) recreated is specified as a function of average cost and average distance traveled per occasion and various combinations of other explanatory variables. Linear, quadratic, and semilog functional forms have been used widely in empirical applications of this model. Linear specifications have been employed often for computational or analytical ease (Burt and Brewer; Brown, Singh, and Castle; Cicchetti, Fisher, and Smith; Clawson and Knetsch). Other functional forms have been chosen frequently on the basis of statistical significance and consistency of the coefficients with theoretical expectations. Examples of a semilog form are Batie, Jensen, and Hogue; and Sawyer and Shulstad. A quadratic expression was chosen by Gum and Martin. A fourth functional form, log-log, also has appeared (Kalter and Gosse; Smith; Wetzstein and Green), but will not be considered here for reasons to be developed later. As the results of this study will demonstrate, the choice of functional form can have a significant effect on consumer surplus values derived from recreation demand equations.

This paper presents a set of decision criteria for the choice between three popular functional forms that have been employed previously in recreation demand equations. The choice between linear and quadratic forms can be made via conventional hypothesis-testing procedures. The Box and Cox transformation procedure often allows choice between linear, semilog, and other power transformations of the dependent variable. The consequences of the choice of a particular functional form on consumer surplus also are investigated. The plan of the paper is first, to specify an appropriate set of regressors; second, to choose an appropriate functional form; and, finally, to demonstrate the effect of functional form on consumer surplus estimates derived from regression cost coefficients of recreation demand equations.

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The Choice of Regressors

An initial problem in specifying any demand equation is the choice of an appropriate set of regressors. For the purposes of this study, it was desired that the selection process be consistent with both economic theory and previous recreation demand studies. From standard neoclassical demand theory, demand equations can be derived which express quantity of a particular commodity consumed as a function of the price of the commodity, prices of related commodities, household income, and other variables—usually socioeconomic in character, which are related to systematic changes in preferences. An example of such a variable would be education. Considering average cost, a suitable proxy for the price of a recreation occasion, the Hotelling-Clawson model, and related models, can be specified within a neoclassical framework. The relevant quantity variable in neoclassical analysis of recreation is number of occasions or trips, rather than days recreated (McConnell).

Given these considerations, number of occasions demanded in this study was specified as a function of average cost per occasion, education and income. Average distance traveled per occasion was also included as an independent variable as a proxy for time spent in travel which may represent an opportunity cost to the recreator (Cesario and Knetsch; Knetsch and Cesario; McConnell; Dwyer and Bowes; Dwyer, Kelley, Bowes). A review of past studies involving recreation demand equations supports the use of the set of regressors chosen for the analysis used in this study (Brown, Singh, Castle; Brown and Nawas; Cicchetti and Smith; Edwards, et al.; Gum and Martin; Kalter and Gosse; Smith; Stevens).

The Choice of Functional Form

Another specification problem involves the selection of an appropriate functional form. As Zarembka (1968) noted in an early application of the Box-Cox transformation, economic theory provides little guidance on appropriate functional form for demand functions. Sinden made a similar observation in specific reference to recreation. Subsequently, McConnell noted that demand theory does

Table 1. Regression Results for Demand Equations for Warm-Water Fishing in Georgia

Functional Form	Intercept	Average Cost	Average Cost Squared	Average Distance Traveled	Education	Income Dummies 2	3	4	5
				Independent Variable					
Linear	44.3785	−.6885	—	−.00029	−1.3108	14.6606	12.1988	26.6267	7.8317
	(4.24)***	(−2.39)**		(−1.67)*	(−1.22)	(1.86)*	(1.24)	(2.18)**	(.61)
Quadratic	43.7331	−1.7379	.0168	−.00026	−1.0790	14.9327	12.1061	6.7415	10.8612
	(4.18)***	(−2.37)**	(1.56)	(−1.49)	(−.99)	(1.89)*	(1.23)	(2.20)*	(.84)
Semilog	3.2958	−.0378	—	−.00001	−.0610	.4455	.588	.9672	.3052
	(12.61)***	(−5.26)***		(−2.22)**	(−2.27)**	(2.26)**	(1.87)*	(3.18)***	(.95)

Note: Number of Observations = 339. *** denotes significance at the .01 level, ** denotes significance at the .05 level, and * denotes significance at the .10 level.

require that the functional form must allow the cross-partial derivative of quantity with respect to price and income to be nonzero. However, all forms used in previous research can be modified to meet this condition. Historically, linear models have been used principally, although quadratic models (involving the inclusion of average cost squared), semilog models (involving the natural logarithm of the dependent variable), and log-log models have been considered. A discontinuous income variable, constructed by recreation survey respondents indicating an appropriate income range, prevented the consideration of a log-log form for this study.[1] Three possibilities, therefore, are considered:

(1) Linear: $Q_i = \beta_0 + \beta_1 AC_i + \beta_2 D_i + \beta_3 I_i + \beta_4 E_i + u_i$,

(2) Quadratic: $Q_i = \beta_0 + \beta_1 AC_i + \beta_2 (AC_i)^2 + \beta_3 D_i + \beta_4 I_i + \beta_5 E_i + u_i$, and

(3) Semilog: $\ln Q_i = \beta_0 + \beta_1 AC_i + \beta_2 D_i + \beta_3 I_i + \beta_4 E_i + u_i$,

where Q_i is quantity of recreation occasions demanded for the ith household, AC_i is average monetary cost per occasion, D_i is average distance traveled per occasion, I_i is income, E_i is years education, and u_i is a stochastic error term.

The recreation activity considered was warm-water fishing in Georgia. All data, which were for 1971, were derived from a previous study of wildlife recreation in the southeastern U.S., completed by the Environmental Research Group at Georgia State University in 1974. From the total Georgia sample, 339 responses from households that participated in warm-water fishing were used as the basis for this study. Participation rates varied from 1 to 400 annual household occasions.

Ordinary least squares results for the three specifications considered are presented in table 1 (t-scores appear in parentheses). Range definitions for the income variables are presented in table 2. A value of one was given to that income variable which corresponded to the respondent's income level and a zero to all other variables. The first income dummy was omitted from each specification and an intercept term included.

Equations (1) and (2) do not meet the theoretical requirement derived by McConnell. To analyze this effect, sets of interaction variables between price and the income dummies were added to these equations. These specifications were estimated with ordinary least squares and the significance of the sets of additional variables tested. The appropriate F statistic was .47 for the linear equation and .31 for the quadratic equation. Because these sets of variables add no significant explanatory power, further analysis is based on the results in table 1 since these specifications are consistent with past research.

[1] Using midpoints of the income ranges employed in the survey questionnaire was considered, but an appropriate value for the open ended "over $20,000" interval could not be determined. For a discussion of the choice between semilog and log-log forms, see Smith.

Table 2. Range of Income Dummies Used in Regression Analysis

Variable	Range
	($)
1	Under 5,000
2	5,001 to 10,000
3	10,001 to 15,000
4	15,001 to 20,000
5	Over 20,000

From table 1, it is not readily apparent which specification is superior. A comparison between the linear and quadratic forms is fairly straightforward. Because the linear and quadratic models differ only by the inclusion of the squared average cost variable, one appropriate test between these two functional forms is provided by the test of the hypothesis that the coefficient of average cost squared is zero. The appropriate t-statistic has the value 1.56 indicating there is no significant difference between the linear and quadratic forms at the .10 level of significance. However, the choice between the linear and semilog forms is not possible by any analysis-of-variance treatment. Thus, the analysis of Box and Cox is used for the comparison between the linear and semilog functional forms in the next section.

A General Transformation Approach

The Box and Cox transformation procedure provides a basis for discrimination between various functional forms. Box and Cox consider the model:

$$(5) \qquad \mathbf{y}^{(\lambda)} = X\beta + \mathbf{u},$$

where X is a matrix of untransformed independent variables, β is a vector of unknown coefficients, $\mathbf{u}$ is an error vector whose elements are normally and independently distributed with mean zero and variance σ^2, and $\mathbf{y}^{(\lambda)}$ is a vector of dependent variables transformed as follows:

$$(6) \qquad \mathbf{y}^{(\lambda)} = \begin{cases} \dfrac{\mathbf{y}^{(\lambda)} - 1}{\lambda} & \text{if } \lambda \neq 0 \\ \ln y & \text{if } \lambda = 0. \end{cases}$$

A λ value of one can be associated with a linear specification and a value of zero with a semilog specification. The transformations described in equation (6) hold for $\mathrm{y} > 0$. Estimates of β, σ^2, and λ, a constant power transformation parameter, can be obtained by regressing $\mathbf{y}^{(\lambda)}$ on X for given λ and then choosing the value of λ which maximizes the concentrated log likelihood function

$$(7) \qquad L_{\max}(\lambda) = \tfrac{1}{2} n \ln \hat{\sigma}^2(\lambda) + (\lambda - 1) \sum_{i=1}^{n} \ln y_i,$$

where n is number of observations and $\hat{\sigma}^2(\lambda)$ is the least-squares estimate of σ^2 for a given λ (Zarembka 1974, p. 86). Zarembka (1968 and 1974) recommends choosing alternative values of λ over a reasonable range, regressing $\mathbf{y}^{(\lambda)}$ on X, and then finding the transformation that maximizes the value of $L_{\max}(\lambda)$. It is also convenient to plot $L_{\max}(\lambda)$ against λ as recommended by Box and Cox (p. 216). A $100(1 - \alpha)$ percent confidence region about $\hat{\lambda}$ is given by

$$(8) \qquad L_{\max}(\hat{\lambda}) - L_{\max}(\lambda) < \tfrac{1}{2}\chi_1^2(\alpha)$$

where $\tfrac{1}{2}\chi_1^2(\alpha) = 1.92$ for $\alpha = .05$. One way to test the hypothesis $\lambda = \hat{\lambda}$ at a specific significance level is to observe whether λ falls within the $100(1 - \alpha)$ percent confidence region.

Following the procedure outlined above λ was varied from -2 to $+2$ in increments of .10 and least squares regressions run using the Georgia warm-water fishing data for the variables discussed earlier. A plot of the log likelihood function is presented in figure 1. The maximizing value of λ is zero, which implies the semilog specification is the appropriate functional form. The 95% confidence interval for λ, equation (8), indicated even λ values of .1 and $-.1$ could be rejected at the $\alpha = .05$ significance level clearly suggesting the linear form ($\lambda = 1$) as inappropriate for the data.[2]

Functional Form and Consumer Surplus

The average cost regression coefficient obtained from recreation demand equations is often used to determine the value of recreational resources in terms of consumer surplus. The valuation technique, often called the Hotelling-Clawson approach, involves utilizing the average cost

[2] At $\lambda = 0$, $L_{\max}(\lambda) = -1034.37$; for $\lambda = .1$ and $\lambda = -.1$, $L_{\max}(\lambda) = -1037.27$ and -1038.18, respectively. The $\alpha = .05$ critical value for $L_{\max}(\lambda)$ was -1036.29.

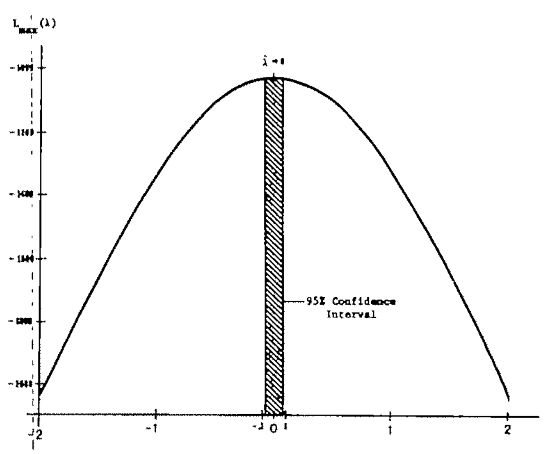

Figure 1. Values of the maximum likelihood function

coefficient as a measure of recreationists' sensitivity to an added cost such as a site entrance fee. According to this technique, a linear equation for the estimated number of occasions demanded becomes

$$(9) \quad \hat{Q}_i = \beta_0 + \beta_1 (AC_i + c) + \sum_{k=2}^{J} \beta_k X_{ik} + u_i,$$

where $\hat{Q}_i$ is the estimated number of occasions demanded by the ith individual, AC_i is average cost, c is added cost, $\sum_{k=2}^{J} \beta_k X_{ik}$ is the sum of other independent variable effects, and u_i is an error term. Gum and Martin suggest subtracting equation (1) from (9) to derive an estimable relationship. Substituting b as an estimate of β_1 and simplifying, the resulting relationship is derived

$$(10) \qquad \hat{Q}_i = Q_i + bc,$$

where Q_i is the actual number of occasions demanded by the ith individual. Integrating this demand curve yields an estimate of consumer surplus

$$(11) \qquad CS_i = \int_0^{c_0} (Q_i + bc)\, dc,$$

where CS_i is consumer surplus for the ith individual and c_0 is the level of added cost which results in no occasions demanded. The value of c_0 can be found by setting $\hat{Q}_i = 0$ in equation (10) and identifying c as c_0. Derivations for the quadratic and semilog forms can be similarly derived. The resulting appropriate demand relationships used for computing consumer surpluses for the quadratic and semilog forms are

$$(12) \quad \hat{Q}_i = Q_i + bc + 2b_2AC(c) + b_2(c)^2, \text{ and}$$

$$(13) \quad \hat{Q}_i = e^{bc}Q_i,$$

where b_2 is the estimated coefficient for the squared average cost term in equation (2). Equations (10), (12), and (13) are presented graphically in figure 2, using the appropriate set of estimated average cost coefficients displayed earlier in table 1. These demand curves are based on a $Q_i = 40$, and an $AC =$ \$2.00, approximately the average number of actual occasions demanded and the mean average cost incurred for the Georgia sample of warm-water fishing participants. Therefore, figure 2 represents the three demand curves, resulting from the functional forms considered, for an average household in the sample.

Consumer surplus was estimated for each of the functional forms described in equations (1), (2), and (3) and summed over all households to obtain sample estimates. The results are presented in table 3.[3] From table 3 and figure 2, it is readily apparent

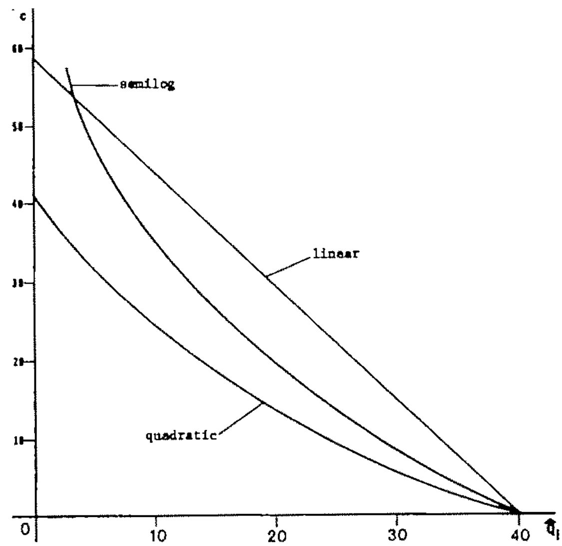

Figure 2. Derived demand curves for warm-water fishing for a representative household in Georgia

that functional form can have a significant effect on estimates of consumer surplus values from recreation demand equations. The linear estimate is approximately three times larger than estimates resulting from either the semilog or quadratic functional forms. The linear estimate of average consumer surplus per occasion is outside the range of values from previous studies compiled by Dwyer, Kelley, and Bowes (pp. 45–64) and may have been questioned on this basis even without statistical consideration of functional forms. However, most previous studies do not clearly indicate that such intuitive considerations of functional forms have been a component of past research. In addition, a previous study has shown that demand parameters used in calculation of consumer surplus can vary among regions, sites, and populations which would confound such intuitive considerations (Ziemer and Musser). This research does indicate that inappro-

Table 3. Consumer Surplus Estimates for Warm-Water Fishing in Georgia from Different Functional Forms of the Demand Equation

Functional Form	Consumer Surplus	Average Consumer Surplus per Occasion
	($)	
Linear	1,004,321	79.09
Quadratic	259,755	20.46
Semilog	335,926	26.46

[3] All figures are sample estimates and would have to be expanded by a population factor to obtain state estimates. An appropriate expansion factor would be equal to the state population divided by the random sample size (which could include nonrecreationists). For our sample this factor is 1558.26.

priate functional form can lead to large errors in estimates of benefits of new public recreation facilities or other public subsidization of wildlife recreation. To avoid such error, it is imperative that surplus estimates be based on the most appropriate functional form.

Conclusions

The purpose of this paper has been to present an analysis of three popular functional forms which have been employed in previous recreation demand studies. The choice between linear and quadratic forms can be made via conventional hypothesis testing procedures. The choice between linear, semilog, and other power transformations of the dependent variable can be assisted by use of the Box and Cox transformation procedure. A secondary objective was to demonstrate the effect the choice of functional form can have on consumer surplus estimates, derived by utilizing average cost regression coefficients from recreation demand equations. Such estimates often are used as an indicator of recreation value and, in some instances, may have had or may eventually have an influence on policy decisions concerning recreation sites and wilderness areas. Results indicate that different functional forms can produce dramatically different consumer surplus estimates. Based on the findings presented here, it is recommended that consideration be given to functional form, as well as to the choice of regressors, when specifying recreation demand equations.

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References

Batie, S. S., R. B. Jensen, and L. G. Hogue. "A Lancasterian Approach for Specifying Derived Demands for Recreational Activities." *S. J. Agr. Econ.* 8(1976):101–7.

Box, G. E. P., and D. R. Cox. "An Analysis of Transformations." *J. Royal Statist. Soc. B* 26(1964):211–52.

Brown, William G., Ajmer Singh, and Emery N. Castle. *An Economic Evaluation of the Oregon Salmon and Steelhead Sport Fisheries.* Oregon State University Agr. Exp. Sta. Tech. Bull. No. 78, Sep. 1964.

Brown, William, and Farid Nawas. "Impact of Aggregation on the Estimation of Outdoor Recreation Demand Functions." *Amer. J. Agr. Econ.* 55(1973): 246–49.

Burt, Oscar R., and Durward Brewer. "Estimation of Net Social Benefits from Outdoor Recreation." *Econometrica* 39(1971):813–27.

Cesario, Frank J., and Jack L. Knetsch. "Time Bias in Recreation Benefit Estimates." *Water Resour. Res.* 6(1970):700–4.

Cicchetti, Charles J., Anthony C. Fisher, and V. Kerry Smith. "An Econometric Evaluation of a Generalized Consumer Surplus Measure: The Mineral King Controversy." *Econometrica* 44(1976):1259–76.

Cicchetti, Charles J., and V. Kerry Smith. *Congestion, Quality Deterioration, and Optimal Use: Wilderness Recreation in the Spanish Peaks Primitive Area.* Washington, D.C.: Resources for the Future, No. 109, July 1973.

Clawson, Marion, and J. L. Knetsch. *Economics of Outdoor Recreation.* Baltimore, Md.: Johns Hopkins University Press, 1966.

Dwyer, John F., and Michael D. Bowes. "Concepts of Value for Marine Recreational Fishing." *Amer. J. Agr. Econ.* 60(1978):1008–12.

Dwyer, John F., John R. Kelley, and Michael D. Bowes. *Improved Procedures for Valuation of the Contribution of Recreation to National Economic Development.* University of Illinois Water Resour. Center Res. Rep. No. 128, Sep. 1977.

Edwards, J. A., K. C. Gibbs, L. J. Guedry, and H. H. Stoevener. *The Demand for Non-Unique Outdoor Recreational Services: Methodological Issues.* Oregon State University Agr. Exp. Sta. Tech. Bull. No. 133, May 1976.

Environmental Research Group. *A Guide to the Data Collecting and Processing System. Economic Evaluation of Wildlife and Wildlife Oriented Resources in the Southeastern U.S.* Georgia State University, Atlanta, 1972.

Gum, Russell L., and William E. Martin. "Problems and Solutions in Estimating the Demand for and Value of Rural Outdoor Recreation." *Amer. J. Agr. Econ.* 57(1975):558–66.

Kalter, R. J., and L. E. Gosse. *Outdoor Recreation in New York State: Projections of Demand, Economic Value and Pricing Effects.* Ithaca, N.Y.: Cornell University, Spec. Ser., 1969.

Knetsch, Jack L., and Frank J. Cesario. "Some Problems in Estimating the Demand for Outdoor Recreation: Comment." *Amer. J. Agr. Econ.* 58(1976):596–97.

McConnell, Kenneth E. "Some Problems in Estimating the Demand for Outdoor Recreation." *Amer. J. Agr. Econ.* 57(1975):330–34.

Sawyer, Thomas G., and Robert N. Shulstad. *Economic Feasibility of Developing Additional Public Outdoor Recreation Areas at Beaver Lake, Arkansas.* University of Arkansas Agr. Exp. Sta. Bull. No. 813, Nov. 1976.

Sinden, J. A. "A Utility Approach to the Valuation of Recreational and Aesthetic Experiences." *Amer. J. Agr. Econ.* 56(1974):61–72.

Smith, V. Kerry. "Travel Cost Demand Models for Wilderness Recreation: A Problem of Non-Nested Hypothesis." *Land Economics* 11(1975):105–11.

Stevens, Joe B. "Recreational Benefits from Water Pollution Control." *Water Resour. Res.* 2(1966):167–82.

Wetzstein, Michael E., and Richard D. Green. "Use of

Principal Component Attractiveness Indexes in Recreation Demand." *West. J. Agr. Econ.* 3(1978):11–21.

Zarembka, Paul. "Functional Form in the Demand for Money." *J. Amer. Statist. Assoc.* 63(1968):602–11.

Zarembka, Paul. "Transformation of Variables in Econometrics." *Frontiers in Econometrics*, pp. 81–104. New York: Academic Press, 1974.

Ziemer, Rod F., and Wesley N. Musser. "Population-Specific Recreation Demand Models and the Consequences of Pooling Sample Data." *West. J. Agr. Econ.* 4(1979):121–28.

Risk and the Demand for Supplemental Irrigation: A Case Study in the Corn Belt

Jeffrey Apland, Bruce A. McCarl, and William L. Miller

Rapid increases in irrigated acreage in the Corn Belt states during recent years have renewed interest in the associated questions of water resource management and the economic feasibility of supplemental irrigation. Corn plant growth and the associated grain yield is particularly sensitive to moisture stress during pollination (June or July), when soil moisture is especially variable. By reducing moisture stress in these periods, supplemental irrigation can increase and stabilize corn yields.

The focus of most economic feasibility studies of irrigation has been to compare the increases in crop revenues to the costs of irrigating—a cost-benefit approach. It has been suggested, however, that stability of yields, and thus the reduction of risk, should be considered among the benefits from irrigation (Carson, Wheaton, Mannering). Although cost-benefit studies have been used to explain the rapid adoption of irrigation in humid areas by exploring the impacts of prices, costs, and technology changes; no thorough analysis has been made of the impact of risk aversion on the demand by farm firms for supplemental irrigation. This study evaluates the implications of risk aversion for the derived demand for supplemental irrigation of corn using a case study approach.

The Analytical Model

A mathematical programming model of a Corn Belt grain farm was used to generate derived demand functions in the analysis. The riskiness of alternative production activities was considered in the model, which was a slight variant of the MOTAD model developed by Hazell. The following is a generalized formulation of the analytical model (Apland).

$$\text{(1) Maximize: } \mathbf{P}'_1\mathbf{X}_1 - \mathbf{P}'_2\mathbf{X} - ar\,\mathbf{L}'(\mathbf{d}^+ + \mathbf{d}^-)$$

$$\text{(2) subject to: } I_1\mathbf{X}_1 - A_1\mathbf{X}_2 \le \mathbf{0},$$

$$\text{(3) } A_2\mathbf{X}_2 - I_2\mathbf{X}_3 \le \mathbf{0},$$

$$\text{(4) } A_3\mathbf{X}_2 \le \mathbf{b},$$

$$\text{(5) } D\,\mathbf{X}_2 - I_3\mathbf{d}^+ + I_3\mathbf{d}^- = \mathbf{0}$$

$$\mathbf{X}_1, \mathbf{X}_2, \mathbf{X}_3, \mathbf{d}^+, \mathbf{d}^- \ge \mathbf{0}.$$

Where $\mathbf{X}_1$ is an n_1x1 vector of outputs, $\mathbf{P}_1$ is an n_1x1 vector of output prices, $\mathbf{X}_2$ is an n_2x1 vector of alternative production activities, $\mathbf{X}_3$ is an n_3x1 vector of variable inputs, $\mathbf{P}_2$ is an n_3x1 vector of variable input prices, A_1 is an n_1xn_2 matrix of coefficients which aggregate $\mathbf{X}_2$ into $\mathbf{X}_1$ (yields), A_2 is an n_3xn_2 matrix of technical coefficients describing the variable input requirements of $\mathbf{X}_2$, A_3 is an n_4xn_2 matrix of technical coefficients describing the fixed factor requirements of $\mathbf{X}_2$, $\mathbf{b}$ is an n_4x1 vector of fixed-factor endowments, D is an n_5xn_2 matrix of observed deviations between expected and actual net revenues for production activities, $\mathbf{d}^+$ is an n_5x1 vector of positive absolute deviations from forecasted net revenues, $\mathbf{d}^-$ is an n_5x1 vector of negative absolute deviations from forecasted net revenues, a is a coefficient which transforms total absolute deviation of returns into an approximation of the standard deviation; $a = \sqrt{\pi n_5/2(n_5 - 1)}$ where n_5 is the number of observations on net revenue used in deviation matrix D, r is the coefficient of marginal risk aversion, I_1, I_2, I_3 are n_1xn_1, n_3xn_3, and n_5xn_5 (respectively) identity matrices, and $\mathbf{L}$ is an n_5x1 vector of ones.

The model above maximizes expected profit less a cost of bearing risk, subject to the technology specified and an endowment of fixed resources. Total absolute deviation[1] (TAD) is used here to form an approximation of the standard deviation of returns and thus has been transformed accordingly by coefficient a. With this transformation and assuming normally distributed deviations in net revenues, $[a\,\mathbf{L}'(\mathbf{d}^+ + \mathbf{d}^-)]$ is an unbiased estimate of the standard deviation of total net revenue (Hazell).

Notice that the coefficient of marginal risk aversion, r, is constant in this linear programming formulation. This parameter is the rate at which the producer will exchange expected net revenue for

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[1] TAD has been shown to be an appropriate risk measure in the case of normally distributed returns or a quadratic utility function (Anderson, Dillon, Hardaker). Also, Tsiang (1972) has suggested this measure when the level of riskiness is small relative to the level of wealth. For a more thorough discussion, see Tsiang (1972, 1974) and Levy.

risk. Endogenous factors such as the income level do not influence the coefficient of marginal risk aversion in this formulation. The implications of this assumption will be mentioned later when the analysis is described.

The production model used in this study was an adaptation of a research and extension model of farm production (McCarl, Candler, Doster, Robbins; Brink, McCarl, Doster). Time characteristics of farming were critical in the model. The chronological nature of the production processes was captured by defining activities and resource endowments over twenty-one consecutive time periods in the production period (within one year). In this way, the effects of planting and harvesting dates on yields were captured. For each crop, activities included land preparation, production, employment of part-time labor, reservation of full-time labor, harvest, grain processing, and marketing. Categories of constraining resources included full-time and part-time labor, land, good field time, tractor and harvest time, and irrigation water. The case farm was a 600-acre, two-man grain farm with a medium-sized complement of machinery. Crops included corn, irrigated corn, soybeans, and wheat. More details on the problem formulation are in Apland.

Risk Data

Net revenues for the analysis were generated using time-series price, cost, and yield data. Crop yields were from experimental data on silt loam—a light soil on which the response to irrigation is typically good. These experimental data were assumed to represent the crop technology currently available under good management. The costs of irrigation (fixed equipment costs and variable operating and maintenance costs) were parameterized in the demand analysis and are not included in the per acre net revenue calculations. Other costs related to irrigation, such as additional fertilizer costs, were used in the calculations. Prices and costs were adjusted to the 1975 level using the parity index. Per acre net revenues appear in table 1.[2] Details on the production data are given in Apland.

Analysis of Results

Derived demand functions of the case farm for supplemental irrigation were generated by parametrically altering the cost coefficient on an irrigation supply activity. Irrigation costs were set at zero, then incrementally increased until irrigation was no longer employed. Corn was the only irrigated crop in the model, and high, medium, and low corn price scenarios were analyzed. To explore the impact of risk aversion, the demand functions were generated for decision makers with three different risk postures—risk indifferent (the profit-maximizing case where $r = 0$) and high and low levels of risk aversion ($r = 2$ and $r = 1$, respectively). This range of risk coefficient was analyzed based on the results of previous studies of risk aversion (Brink and McCarl). Although these studies have found no single value of the risk coefficient which best explains the production behavior of farmers, values within this range appear to be most reasonable. With the three corn price levels (at the 1976 expected level and 5% above and below the 1976 expected level), and three levels of the risk coefficient, nine derived demand functions were generated. Table 2 presents the results of the experiments.

Table 1. Actual Net Revenue per Acre by Crop

	Corn	Irrigated Corn	Soybeans	Wheat
1968	99.50	141.50	153.78	75.39
1969	95.11	183.12	128.30	66.66
1970	146.56	205.44	149.14	74.57
1971	−11.47	235.52	164.85	55.29
1972	178.11	186.68	194.97	59.28
1973	186.33	188.16	411.91	100.20
1974	268.19	263.52	255.83	120.31
1975	252.85	263.83	235.38	78.78

Note: Does not include the fixed and variable costs of the irrigation operation, but does include associated costs such as added fertilizer costs.

Figure 1 shows the derived demand functions under the medium corn price scenario. The dotted lines identify the 1976 per acre irrigation cost ($53.50), and costs $10 above and below the 1976 level. Marked differences occurred between the derived demands for the profit-maximizing firm and those in the risk-averse cases. As the coefficient of marginal risk aversion increased from zero, the derived demand functions became more inelastic—changes in per acre costs led to smaller changes in irrigated acreage. Also, optimal acreages in the cost range from $43.50 to $63.50 begin to converge between 150 and 250 acres of irrigated corn. The demand functions display a crossing behavior resulting from the risk-averse firm's tendency to maintain a higher level of crop diversification than the profit-maximizing (risk indifferent) firm.

At the current price of irrigation ($53.50) the irrigation of corn appears to be a rather marginal proposition for the profit maximizer ($R1$). In all cases the price $58.50 causes the profit maximizers demand to go to zero. Thus, an interesting result is that profit maximizers would tend either to not irrigate or to irrigate only small parcels. The model indi-

[2] These net revenue calculations are for a "neutral" combination of planting and harvesting periods—yields and costs in the model change for different planting and harvesting dates and thus per acre net revenues were appropriately adjusted.

Table 2. Acres of Irrigated Corn Grown at Various per Acre Irrigation Costs for Three Levels of the Coefficient of Marginal Risk Aversion (R) and Three Corn Price Levels

Irrigation Cost $/Acre	Acres of Corn Irrigated								
	1976 Less 5%[a]			1976			1976 Plus 5%		
	$R1$[b]	$R2$	$R3$	$R1$	$R2$	$R3$	$R1$	$R2$	$R3$
0.0	548	408	266	548	517	279	580	548	280
3.5	548	316	264	548	449	266	565	548	280
8.5	548	316	256	548	422	266	554	548	266
13.5	548	316	215	548	408	266	548	517	266
18.5	449	264	215	548	280	266	548	372	266
23.5	392	264	215	548	280	266	548	372	266
28.5	354	215	215	548	266	256	548	355	266
33.5	178	215	215	548	264	256	548	351	266
38.5	141	215	215	449	256	215	548	351	264
43.5	127	215	215	284	256	215	466	267	256
48.5	0	215	215	253	215	215	388	266	256
53.5	0	215	215	127	215	215	253	264	256
58.5	0	207	215	0	215	215	0	256	256
63.5	0	141	215	0	215	215	0	256	215
68.5	0	141	215	0	194	215	0	256	215
73.5	0	127	215	0	194	215	0	194	215
78.5	0	117	215	0	179	215	0	194	215
83.5	0	117	215	0	141	215	0	194	215
88.5	0	117	179	0	141	194	0	194	215
93.5	0	117	141	0	117	194	0	191	194
98.5	0	117	141	0	117	194	0	141	194

[a] Price expectations for 1976 were estimated by using the average of 1974 and 1975 returns. The results were $2.50, $6.00, and $4.23, respectively, for corn, soybeans, and wheat. The corn price was both increased and decreased by 5% in the demand analysis.
[b] $R1$ denotes the risk neutral or profit-maximizing case where $r = 0.0$. $R2$ and $R3$ represent the risk-averse cases where $r = 1.0$ and $r = 2.0$, respectively.

cates that only risk averters would be involved in significant irrigation efforts at current cost levels.

Risk attitude and irrigation price had several impacts on crop acreages. At high irrigation prices with high risk parameters diversification is present between nonirrigated corn and soybeans. At low prices with high risk aversion (r = 2) the acreage was diversified between irrigated corn and soybeans. Increasing (or decreasing) the risk aversion parameter led to a more (less) diversified crop plan between corn (the profit maximizer tended to grow more corn) and soybeans and also led to a substitution of irrigated for nonirrigated corn. Decreasing the irrigation cost tended to lead to the substitution of irrigated for nonirrigated acreage.

The constancy of the marginal risk aversion coefficient (r) should be mentioned at this point. Of course, as irrigation costs change, the farm firm reallocates its resources to maximize managerial income (discounted by risk, in the risk averse case). Over the range of irrigation costs considered in this analysis ($43.50 to $63.50), managerial income changes less than 5%. As such, the risk coefficient is assumed constant over this income range.

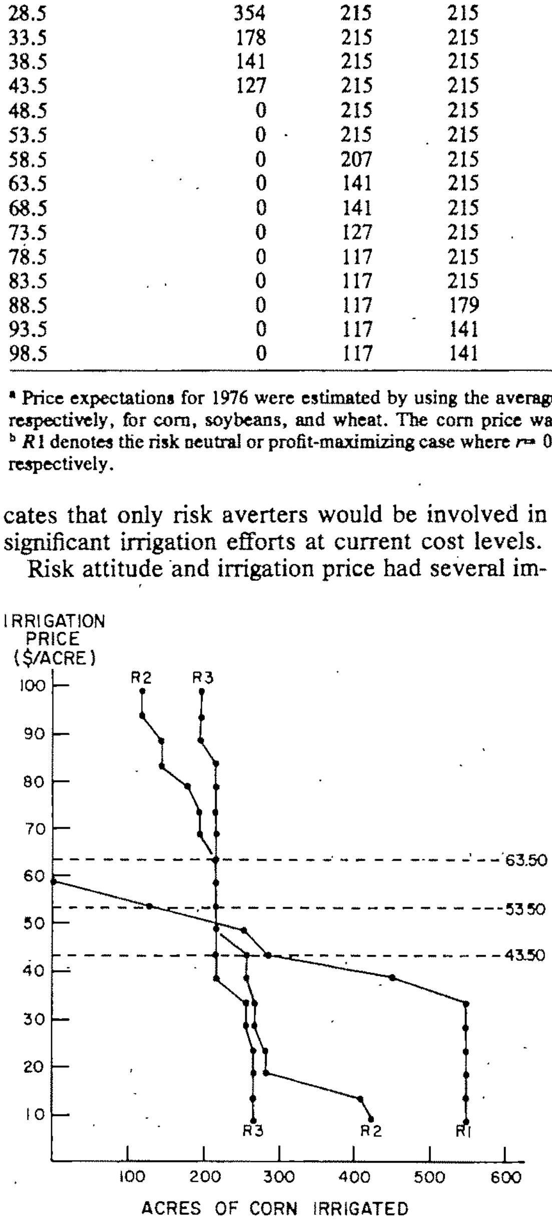

Figure 1. Derived demand functions at medium corn prices for three levels of risk: $R1$ for r = 0.0, R^2 for r = 1.0, and $R3$ for r = 2.0

Conclusions

The results of this analysis indicate that the influence of a manager's risk posture has a marked impact on the firm's demand for irrigation. Any descriptive analyses of the adoption of irrigation should, therefore, consider the implications of risk

aversion. This study suggests that even at high irrigation costs and low corn prices, irrigation technologies may be employed by the rational farm firm manager who is averse to risk. In fact, risk neutral decision makers may not irrigate at current prices; however, risk averters will. Further, the demand for irrigation as a factor of production becomes increasingly inelastic when risk aversion is evident, reflecting the farmer's propensity to eliminate the "risky" nonirrigated crop and to maintain a risk averting diversified crop mix.

Agricultural policy makers are increasingly concerned with farm income stabilization. To the extent that price supports and other policies contribute to income stability, the adoption of irrigation technologies as an aversion to risk would be dampened. Although inferences about the aggregate behavior of Corn Belt farmers in the adoption of supplemental irrigation have not been developed from this microeconomic analysis, this study demonstrates that it is important to address the question of risk in studies of the aggregate demand for irrigation.

The model used in this descriptive analysis has potential in prescriptive applications as well. The programming model could be used in an efficiency analysis of irrigation. By parameterizing technical and economic coefficients, the profitability and risk benefits from irrigating could be "pretested" for a variety of farm classes. Such data could then be used to narrow down the circumstances under which supplemental irrigation may be a viable technology.

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References

Anderson, Jock R., John L. Dillon, and Brian Hardaker. *Agricultural Decision Analysis*. Ames: The Iowa State University Press, 1977.

Apland, Jeffrey. "A Microeconomic Analysis of Supplemental Irrigation with Consideration of Risk." M.S. thesis, Purdue University, 1977.

Brink, Lars, Bruce A. McCarl, and D. Howard Doster. *Methods and Procedures in the Purdue Crop Budget (Model B-9): An Administrator's Guide*. Purdue University Agr. Exp. Sta. Res. Bull. 121.

Brinks, Lars, and Bruce A. McCarl. "The Tradeoff between Expected Return and Risk among Corn Belt Farmers." *Amer. J. Agr. Econ.* 60(1978):259–63.

Carson, E. E., R. Z. Wheaton, and J. V. Mannering. *Irrigation of Field Crops in Indiana*. Purdue University Ext. Bull. ID-119, 1977.

Hazell, P. B. R. "A Linear Alternative to Quadratic and Semivariance Programming for Farm Planning under Uncertainty." *Amer. J. Agr. Econ.* 53(1971):53–62.

Levy, Haim. "The Rationale of the Mean-Standard Deviation Analysis: Comment." *Amer. Econ. Rev.* 64(1974):434–41.

McCarl, Bruce A., Wilfred V. Candler, Howard Doster, and Paul R. Robbins. "Purdue Top Farmer Automatic Crop Budget: Design, Application and Experience." *Can. J. Agr. Econ.* 25(1977):17–30.

Thompson, K. J., and P. B. R. Hazell. "Reliability of Using the Mean Absolute Deviation to Derive Efficient EV Farm Plans." *Amer. J. Agr. Econ.* 54(1972):503–6.

Tsiang, S. C. "The Rationale of the Mean-Standard Deviation Analysis Skewness Preference, and the Demand for Money." *Amer. Econ. Rev.* 62(1972):354–71.

Tsiang, S. C. "The Rationale of the Mean-Standard Deviation Analysis: Reply and Errata for Original Article." *Amer. Econ. Rev.* 64(1974):442–50.

A Theoretical Note on Aggregation of Linear Programming Models of Production

Thomas H. Spreen and Takashi Takayama

Linear programming models have been used widely to solve the firm's resource allocation problem. If the model is specified properly, then its solution will give the firm's profit-maximizing levels of output and factor use. The model's ability to predict firm adjustment to changes in a variety of exogenous factors is well-known. It is the model's flexibility and easy application that inevitably led to its use in aggregate studies.

The transition from firm level to regional, industrial, or even national analysis is the source of the aggregation problem. As all firms are not alike, we wish ideally to model every firm and sum up their solution vectors to generate an aggregate solution. The modeling of individual firms of an industry or region of any size, however, is unmanageable, and thus, firms are partitioned into "homogenous" groups. The question becomes how best to form these groups. Studies which have attempted to define empirical rules and practical guidelines include Frick and Andrews, Sheehy and McAlexander, and Buckwell and Hazell. A theoretical curiosity, however, has emanated. Stated simply, do there exist conditions under which a group of firms can be represented by an aggregate model with no loss of information? Day first proposed a set of such conditions upon which subsequent attacks of various sorts have been mounted by Miller, Lee, Marenco, and Paris and Rausser. The purpose of this paper is to reexamine the aggregation issue and offer additional theoretical results.

Issues and Definitions

Consider a set of N firms, each faced with the problem of determining that vector $\mathbf{x}^i$ which

(1) Maximizes $\mathbf{P}^{i\prime}\mathbf{x}^i$

$$\text{subject to } A^i\mathbf{x}^i \leq \mathbf{b}^i, \text{ and}$$
$$\mathbf{x}^i \geq 0 \qquad i = 1, \ldots, N,$$

where $\mathbf{P}^i$ is a nxl vector of prices or net returns, A^i is the mxn technology matrix, and $\mathbf{b}^i$ is the mxl vector of resource availabilities to the ith firm.

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Suppose the following specification represents an aggregate model of the N firms:

$$\text{(2)} \qquad \text{Max } \mathbf{P}'\mathbf{x} \text{ subject to } A\mathbf{x} \leq \mathbf{b}, \text{ and } \mathbf{x} \geq 0,$$

which is of the same dimension as the firm models. The aggregation of the firm models given by (1) into an aggregate model given by (2) is said to be totally consistent (Ijiri) if

$$\text{(3)} \qquad x^* = \sum_i \mathbf{x}^{i*},$$

where "*" denotes the optimal solution to each of the models, for any values of $\mathbf{P}^i$ and $\mathbf{b}^i$. Guccione and Oguchi have demonstrated the impossibility of achieving totally consistent aggregation. They assert that the conditions first proposed by Day; namely (a) $A^i = A^j$ (b) $\mathbf{b}^i = \lambda_i\, \mathbf{b}^j$, and ($c$) $\mathbf{P}^i = \gamma_i\, \mathbf{P}^j$ for all i and j, should be considered as restricted domains of the exogenous data. Day's original work also specified a fourth condition which was later shown by Marenco to be redundant.

Previous authors have accepted (3) as the definition of perfect or exact aggregation. Once we restrict ourselves to the case where all firms face the same price vectors, $\mathbf{P}$ ($\mathbf{P}^i = \lambda_i\mathbf{P}^j$ for all i and j says that each firm's price vector differs from all others only by a constant of proportionality. Thus we can assume, without loss of generality, that $\mathbf{P}^i = \mathbf{P}^j = \mathbf{P}$) as implied by condition (c), a more precise definition can be stated. First, let $\mathbf{x}^i(\mathbf{P})$ denote the optimal solution to the ith firm's model given a price vector $\mathbf{P}$.

DEFINITION 1: *Aggregation bias is said to be zero if given any price vector* $\mathbf{P}(\geq 0)$, *the aggregated vector of individual firm optimal output vectors,* $\mathbf{x}^*(\mathbf{P})$, *is exactly the same as the solution* $\mathbf{x}(\mathbf{P})$ *of an aggregate model for the same* $\mathbf{P}$.

DEFINITION 2: *If aggregation bias is zero in the sense of definition 1, for all* $\mathbf{P}(\geq 0)$, *the aggregate model is said to be an exact aggregation model. In terms of norms, one can say that the aggregation is exact if* $d[\mathbf{x}^*(\mathbf{P}), \mathbf{x}(\mathbf{P})] = \sqrt{\sum_j [x^*_j(\mathbf{P}) - x_j(\mathbf{P})]^2} = 0$ *for all* $\mathbf{P} \geq 0$. (The terminology "exact aggregation model" was first used by Miller but since has been adopted by other authors on the subject.)

Note that definition 1 recognizes that the solution **x**(**P**) to a linear programming problem can be viewed as a mapping from price (net revenue) space to commodity space; **P** is mapped to **x**(**P**). Furthermore, this mapping is not one-on-one. This is a critical point. It is not sufficient to show **x**(**P**) = **x***(**P**) for some **P**.

To clarify this point, consider a simple two-firm example which satisfies Day's theorem:

Example 1:

$$\text{Firm 1}\quad \begin{aligned} X_1^1 + X_2^1 &\leq 10 \\ X_1^1 \qquad &\leq 5 \\ X_1^1,\quad X_2^1 &\geq 0 \end{aligned} \qquad \text{Firm 2}\quad \begin{aligned} X_2^2 + X_2^2 &\leq 20 \\ X_1^2 \qquad &\leq 10 \\ X_1^2,\quad X_2^2 &\geq 0. \end{aligned}$$

Using Day's theorem, the aggregate model is

$$\begin{aligned} X_1 + X_2 &\leq 30 \\ X_1 \qquad &\leq 15 \\ X_1,\quad X_2 &\geq 0. \end{aligned}$$

Each individual and aggregate feasibility frontier is depicted in figure 1.

If the price vector is, say, **P** = (1,1/2), the optimum output for the individual firms are B_1 and B_2 with the corresponding aggregate model solution B and aggregation bias is zero. Suppose, however, that the price vector is **P** = (1,1). Individual firms face the problem of implementation because optimal solutions lie on the line segment A_1B_1 for Firm 1 and A_2B_2 for Firm 2. Individual firms, however, have to implement their plans. Assume Firm 1 takes B_1 as its plan and Firm 2 takes A_2. The aggregated implemented plan is C.

The aggregated model is then solved for its optimum plan for **P** = (1,1). The line segment AB is the solution set. Researchers in charge of the aggregated model face uncertainty in attempting to project or pinpoint what would be the realized supply for the region. Not knowing individual plans already implemented, they may choose point B as their projection. But as point B does not correspond with the aggregated solution, point C, "aggregation bias" is nonzero.

The existence of alternative optimal primal solutions for some price vectors precludes the existence of an exact aggregation model. When a price vector **P** is parallel to one of the constraints, the mapping from price space to quantity space defined by the linear programming model is a one-to-many mapping. As pointed out by Ijiri, if the microfunction (the firm linear programming model) is not one-to-one, we cannot hope to find a macrofunction (the aggregate model) which satisfies the conditions of definition 2.

On the other hand, point C, the aggregated output vector, does lie in the solution set of the aggregate problem. Thus, linear programming models can exhibit zero aggregation bias, but not in the sense of definition 1. This leads us to consider the concept proposed by Frick and Andrews which we state as

DEFINITION 3: *Aggregation bias is said to be zero if for any given price vector* **P**(≥0), *the aggregated vector of individual firm optimal output vector, say* **x*** (**P**) *is contained in the solution set* **X**(**P**) *of the aggregate model for the same* **P**.

DEFINITION 4: *If aggregation bias is zero in the sense of definition 3 for all* **P**(≥0), *the aggregate model is said to be a semi-exact aggregation model. In terms of norms, one can say that the aggregation is semi-exact if*

$$\min_{\mathbf{x}(\mathbf{P})\in\mathbf{X}(\mathbf{P})} \{d[\mathbf{x}^*(\mathbf{P}),\mathbf{x}(\mathbf{P})]\} = 0 \qquad \text{for all } \mathbf{P} \geq 0.$$

From our discussion above, we see that linear programming models of production can be semi-exact aggregation models. We summarize our discussion in:

THEOREM 1: *Given a set of N linear programming models and an aggregate model, then the aggregate model cannot satisfy exact aggregation for all price vectors* (**P** ≥ 0), *but may be a semi-exact aggregation model.*

The implication of theorem 1 leads us to ask if linear programming models do not satisfy exact aggregation, are there other functional forms that do satisfy exact aggregation? The answer is yes, as we shall see in the next section.

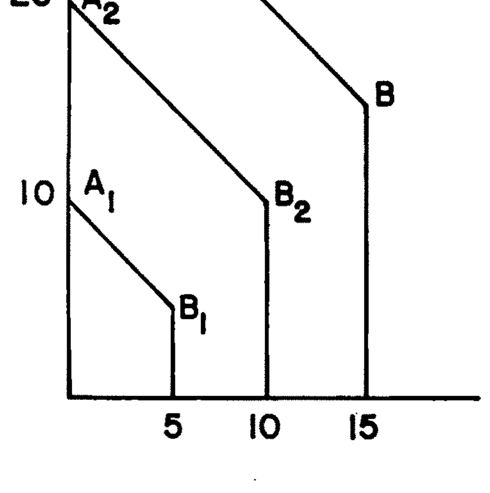

Figure 1. Feasibility frontiers

Exact Aggregation

Linear programming models of production can not satisfy exact aggregation because in linear programming the mapping from price (net revenue) space to commodity space is upper semicontinuous, not continuous. If we restrict ourselves to those constrained optimization models of production in which the mapping is continuous, then exact aggregation is possible.

Consider a set of N individual firms, each with a production efficiency frontier given by $F_i(x) = 0$ where x is k-dimensional, and which satisfy the following conditions.

Condition 1: $F_i(x)$ for all i, are continuous, and at least twice differentiable.

Condition 2: For all $F_i(x) = 0$,

$$\frac{dx_j}{dx_l} \leq 0,$$

for all j and $l \epsilon \{1, 2, \ldots, k\}$ and $j \neq l$, and all $i \epsilon \{1, 2, \ldots, N\}$.

Condition 3: The Hessian of F_i is negative definite everywhere in the nonnegative commodity domain, for all $i = 1, \ldots, N$.

Condition 1 is a smoothness condition for each of N individual production efficiency surfaces. Condition 2 excludes the possibility of discontinuities of the production efficiency frontier such as at B and D shown in figure 2.[1]

Condition 3 guarantees that the individual production efficiency frontiers are smoothly bulging out away from the origin, or the production feasibility set $X_i = \{x|F_i(x) = 0, x \geq 0\}$ forms a strictly convex set. We now state:

THEOREM 2: *If $F_i(x)$ satisfies conditions 1, 2, and 3 for all i, then exact aggregation exists.*

Proofs for this theorem can be found elsewhere (e.g., Takayama and Judge, chap. 15, or Nikaido, chap. 10). An example of the application of this theorem should serve to clarify its meaning.

Example 2: Consider two firms with the following production efficiency frontiers:

$$\text{Firm 1:}\quad 100 - (x_1^1)^2 - 4(x_2^1)^2 = 0$$
$$\text{Firm 2:}\quad 25 - (x_1^2)^2 - 4(x_2^2)^2 = 0.$$

For a given vector $\mathbf{P} = (1,p)$, one can obtain the following optimal outputs for 1 and 2:

$$x_1^1\,(\mathbf{P}) = \frac{10}{\sqrt{1 + (p^2/4)}}$$

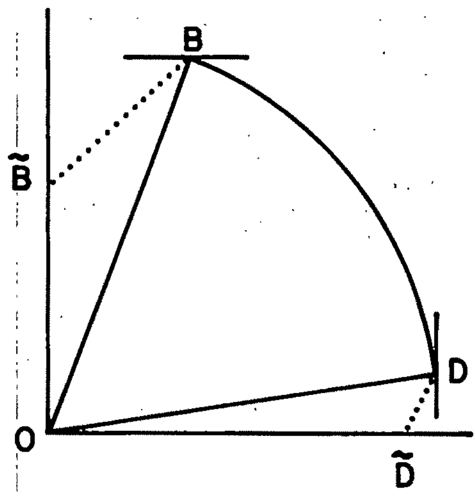

Figure 2. Efficiency frontier

Firm 1

$$x_2^1\,(\mathbf{P}) = \frac{10_p}{\sqrt{1 + (p^2/4)}},$$

$$x_1^2\,(\mathbf{P}) = \frac{5}{\sqrt{1 + (p^2/4)}}$$

Firm 2

$$x_2^2\,(\mathbf{P}) = \frac{5_p}{\sqrt{1 + (p^2/4)}}.$$

By setting $x_1 = x_1^1(\mathbf{P}) + x_1^2(\mathbf{P})$ and $x_2 = x_2^1(\mathbf{P}) + x_2^2(\mathbf{P})$ and eliminating p from x_1 and x_2, the aggregate production efficiency is found to be

$$225 - (x_1)^2 - 4(x_2)^2 = 0.$$

It can be seen the $\mathbf{x}^*(\mathbf{P})$, the sum of the individual firm solutions equal $\mathbf{x}(\mathbf{P})$, the aggregate solution, for all $\mathbf{P}$, and $x(\mathbf{P})$ can be decomposed uniquely into x_k^i (P)'s for $i = 1, 2$, and $k = 1, 2$. Thus "exact aggregation" is clearly exhibited.

The problem is not as easy once one introduces different functional forms for the individual production efficiency frontiers such as

$$\text{Firm 1:}\quad 100 - (x_1^1)^2 - 4(x_2^1)^2 = 0$$
$$\text{Firm 2:}\quad 25 - 4(x_1^2)^2 - (x_2^2) = 0.$$

We challenge the reader to derive, if possible, an analytical expression of the aggregate production efficiency frontier in the form $F(x) = 0$.

The above observations lead us to a more restrictive theorem. First, a definition is required.

DEFINITION 5: *We say that the functions $F^i(x)$, $i = 1, \ldots, N$ are homothetic of the same class if there exist monotonic increasing transformations h^i, such that $h^i[F^i(x)] = G(x)$ for all $i = 1, \ldots, N$ where $G(x)$ is homogenous of degree 1* (Hanoch).

THEOREM 3: *Let $F^i(x) = 0$, $i = 1, \ldots, N$ represent the production efficiency frontiers for a set*

[1] This is due to the fact that the price vector is restricted to be nonnegative; that is, $\mathbf{P} \geq 0$. However, if we allow $\mathbf{P}$ to contain negative components, these discontinuities will disappear as shown by the dotted segments $B\tilde{B}$ and $\tilde{D}D$.

of firms. Assume the $F^i(x)$ satisfy conditions 1–3 above and are homothetic of the same class. Then there exists an aggregate production efficiency frontier, $F(x) = 0$, which is an exact aggregation model of the individual firms.

A proof of this theorem appears in Spreen and Takayama. The homothetic restriction insures that for every price vector **P**, the marginal rate of product transformation for every firm will be identical; thus the optimal output vectors for all firms will differ only by a constant of proportionality, as we observed in example 2.

Semi-Exact Aggregation

Now we turn our attention towards stating a set of sufficient conditions under which linear programming models of production satisfy semi-exact aggregation. In this section, we state and prove a modification of Miller's theorem.

Let us assume that each of the individual firm models satisfy the following condition:

Condition 4: For any price (net revenue) vector **P**, the order and number of binding constraints for each $x^i(\mathbf{P})$, $i = 1, \ldots, N$ are the same. This condition implies two requirements: (a) at each price (net revenue) vector faced by the firms, they all produce exactly the same number and kind of commodities; in other words, the same activities are in solution for every firm, [this is the qualitatively homogenous output vector (*QHOV*) assumption of Miller]; and (b) for each price (net revenue) vector, the constraints which are binding are exactly the same for each firm.

The second requirement of condition 4 excludes the possibility that for each price (net revenue) vector, all firms satisfy the *QHOV* property, but some firms may have one or more resources in disposal, which are binding for other firms. This possibility must be excluded because in the aggregate model, the availabilities of resources to each firm are added together; and thus, in the example above, the impact would be that the surplus of a resource from one firm could be "transferred" to another firm in the aggregate model. The result would be that the aggregated output vector of the individual firm solutions would show less production than the solution from the aggregate model.

THEOREM 4: *Given a set of N firm models as specified in (1) with solution vectors $\mathbf{x}^i(\mathbf{P})$, then sufficient conditions for the aggregate model*

$$\begin{aligned} &\text{Max } P'x \\ &\text{Subject to } Ax < b \\ &\qquad\qquad x \geq 0, \end{aligned}$$

to be a semi-exact aggregation model are that

(i) *$u_i^1 A_i^1 = u_i^2 A_i^2 = \ldots = u_i^N A_i^N = A_i$ for any scalars u_i^j, $0 < u_i^j < \infty$ where A_i^j is the ith row of the jth firm's technology matrix and A_i is the ith row of the aggregate matrix.*

(ii) *$b_i = \sum_{j=1}^{N} b_i^j/u_i^j$ where b_i^j is the availability of resource i to firm j.*

(iii) *The set $x^i = \{x^i | A^i x^i \leq b^i, x^i \geq 0$ is not empty.*

(iv) *The individual firm models satisfy Condition 4.*

Proof: Condition i insures that the technology matrix for each firm is of the same dimension and that each row of A^i is proportional to A^j, for all $i \neq j$. Hence, by dividing each row and right-hand side through by the appropriate constant or proportionality u_j^i, one can assume, without loss of generality, that

$$A^1 = A^2 = \ldots = A^N = A, \text{ and}$$

$$\sum_{i=1}^{N} b^i = b.$$

We differentiate between two cases.

Case 1: Suppose that the price vector **P** is not proportional to any row of A. Then we know that each firm's solution $\mathbf{x}^i(\mathbf{P})$ will be a vertex solution. At this vertex we can identify the activities in solution and the binding constraints. Condition 4 insures that these will be the same for every firm. Let $A_p{}^i$ be that sub-matrix of A^i corresponding to the activities in solution and binding constraints. We know that $A_p{}^i$ is square and nonsingular, and the optimal solution $\mathbf{x}^i(\mathbf{P})$ is given by

$$\mathbf{x}^i(\mathbf{P}) = (A_p{}^i)^{-1}\mathbf{b}_p{}^i,$$

where $\mathbf{b}_p{}^i$ is the vector of right-hand-side values corresponding to the binding constraints. Because $A^i = A$ for all $i = 1, \ldots, N$, then

$$\mathbf{x}^i(\mathbf{P}) = (A_p)^{-1}\mathbf{b}^i.$$

Thus,

$$\begin{aligned} \mathbf{x}^*(\mathbf{P}) &= \sum_{i=1}^{N} \mathbf{x}^i(\mathbf{P}) = \sum_{i=1}^{N} (A_p)^{-1}\mathbf{b}_p{}^i \\ &= (A_p)^{-1} \sum_{i=1}^{N} \mathbf{b}_p{}^i = (A_p)^{-1}\mathbf{b}_p = x(p), \end{aligned}$$

because $\sum_{i=1}^{N} \mathbf{b}^i = b$. Thus when the price vector **P** is not proportional to any row of A,

$$\mathbf{x}^*(\mathbf{P}) = \sum_{i=1}^{N} x^i(\mathbf{P}) = \mathbf{x}(\mathbf{P}).$$

Case 2: Suppose that the price vector **P** is proportional to some row of A, say row s. The optimal solution for each firm will be the set

$$\begin{aligned} \mathbf{x}^i(\mathbf{P}) = (\mathbf{x}^i | A_s{}^i\mathbf{x}^i &= \mathbf{b}_s{}^i \\ \text{and } A_r{}^i\mathbf{x}^i &\leq \mathbf{b}_r{}^i \\ \text{for } r = 1, \ldots, L &\text{ and } r \neq s), \end{aligned}$$

where $A_s{}^i$ denotes row s of technology matrix and $\mathbf{b}_s{}^i$ is the sth entry in the resource vector of the ith firm.

Because $A^i = A$ for all i, then

$$\mathbf{x}^i(\mathbf{P}) = (\mathbf{x} | A_s\mathbf{x}^i = \mathbf{b}_s{}^i \text{ and } A_r\mathbf{x}^i \leq \mathbf{b}_r{}^i \text{ for } r = 1, \ldots, L \text{ and } r \neq s).$$

Define Y to be the set

$$Y = \sum_{i=1}^{N} \mathbf{x}^i(\mathbf{P}) = (\mathbf{x} | A_s\mathbf{x} = \mathbf{b}_s \text{ and } A_r\mathbf{x} \leq \mathbf{b}_r \text{ for } r = 1, \ldots, L \text{ and } r \neq s).$$

However, Y is the solution set to the aggregate, as it can be written as

$$\mathbf{x}(\mathbf{P}) = (\mathbf{x} | A_s\mathbf{x} = \mathbf{b}_s \text{ and } A_r\mathbf{x} \leq \mathbf{b}_r \text{ for } r = 1, \ldots, L\ r \neq s),$$

since $A^i = A$ for all i and $\mathbf{P}$ is proportional to row s of A. Thus $\mathbf{x}^*(\mathbf{P}) = \sum_{i=1}^{N} \mathbf{x}^i(\mathbf{P})$ is contained in the solution set $\mathbf{x}(\mathbf{P})$ for the aggregate problem *QED*.

The example below is given to illustrate Theorem 4.

Example 3: Consider the following individual LP models

$$\text{Firm 1}\quad \begin{array}{l} \text{Max } \mathbf{P}'\mathbf{x} \\ \text{Subject to} \\ \mathbf{x}_1 + 2\mathbf{x}_2 \leq 10 \\ 2\mathbf{x}_1 + \mathbf{x}_2 \leq 10 \\ \mathbf{x}_1, \quad \mathbf{x}_2 \geq 0 \end{array} \qquad \text{Firm 2}\quad \begin{array}{l} \text{Max } \mathbf{P}'\mathbf{x} \\ \text{Subject to} \\ \mathbf{x}_1 + 2\mathbf{x}_2 \leq 15 \\ 2\mathbf{x}_1 + \mathbf{x}_2 \leq 18 \\ \mathbf{x}_1, \quad \mathbf{x}_2 \geq 0. \end{array}$$

The aggregate model is

$$\begin{array}{l} \text{Maximize } \mathbf{P}'\mathbf{x} \\ \text{Subject to} \\ \mathbf{x}_1 + 2\mathbf{x}_2 \leq 25 \\ 2\mathbf{x}_1 + \mathbf{x}_2 \leq 28 \\ \mathbf{x}_1, \quad \mathbf{x}_2 \geq 0. \end{array}$$

Implications for Empirical Problems

Theorem 1 may be named the "impossibility theorem of exact aggregation in linear programming models." We have found that even for a set of firms that satisfy Day's restrictive conditions, an aggregate model cannot be constructed which will be an exact aggregation model for all nonnegative price vectors. Further investigation showed that when we leave the domain of piecewise linear production frontiers (linear programming) and consider only the nonlinear case, exact aggregation is possible, but the aggregate model is analytically difficult to construct unless one imposes further restrictive assumptions. Thus, the possibility of constructing an exact aggregation model in an empirical study is remote.

This conclusion motivates the introduction of the terminology "semi-exact" aggregation. Theorem 4 shows that under still restrictive conditions, a semi-exact aggregation model can be constructed which is of the same dimension as the firm models. Its direct use in empirical studies, however, is limited.

The entire theoretical discussion on aggregation, including this paper, has resulted in little for empirical studies, because all studies presuppose knowledge about every individual firm. As Paris and Rausser noted, the empirical researcher rarely possesses this information. Data are more likely to be available for only a sample of firms or at the aggregate level. Guidance is sought on how best to design a sample to minimize cost, size of the aggregate model, and aggregation bias. We found, in our proof of Theorem 4, that the crucial condition for semi-exact aggregation is that for every price vector, all firms must have the same set of activities in solution. This result is strikingly similar to the aggregation procedure developed by Sheehy and McAlexander. They proposed that firms should be classified on the basis of the most limiting resource for each activity. This criterion is a restatement of the *QHOV* assumption. The implication for empirical studies is that the production patterns of firms is the proper rule of aggregation. Furthermore, cross-section and time-series data is required to examine how firms react to changing price vectors and thus allow researchers to identify those firms whose solution vectors are identical for a given vector, but react quite differently when faced with alternative price vectors.

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References

Buckwell, Allan E., and Peter B. R. Hazell. "Implications of Aggregation Bias for the Construction of Static and Dynamic Linear Programmings Supply Models." *J. Agr. Econ.* 23(1972):119–34.

Day, Richard H. "On Aggregating Linear Programming Models of Production." *J. Farm Econ.* 45(1963): 797–813.

Frick, George E., and R. A. Andrews. "Aggregation Bias and Four Methods of Summing Farm Supply Functions." *J. Farm Econ.* 47(1965):696–700.

Guccione, Antonio, and Noriyoshi Oguchi. "A Note on the Necessary Conditions for Exact Aggregation of Linear Programming Models." *Math. Program.* 12(1977):133–35.

Hanoch, Giora. "Homotheticity, Homogeneity, and Separability." Disc. Pap. No. 98, Harvard Institute of Economic Research, Dec. 1969.

Ijiri, Yuji. "Fundamental Queries in Aggregation Theory." *J. Amer. Statist. Res.* 66(1971):766–82.

Lee, John E. "Exact Aggregation: A Discussion of Miller's Theorem." *Agr. Econ. Res.* 18(1966):58–61.

Marenco, G. "Exact Aggregation With Linear Programming Models—A Note on the Sufficient Condition Proposed by R. H. Day." *Amer. J. Agr. Econ.* 51(1969):684–86.

Miller, Thomas A. "Sufficient Conditions for Exact Aggregation in Linear Programming Models." *Agr. Econ. Res.* 18(1966):52–7.

Nikaido, H. *Introduction to Sets and Mapping in Modern Economics.* Amsterdam: North-Holland Publishing Co., 1970.

Paris, Quirino, and Gordon C. Rausser. "Sufficient Conditions for Aggregation of Linear Programming Models." *Amer. J. Agr. Econ.* 55(1973):659–66.

Sheehy, Seamus J., and R. H. McAlexander. "Selection of Representative Benchmark Farms for Supply Estimation." *Amer. J. Agr. Econ.* 47(1965):681–95.

Spreen, Thomas H., and T. Takayama. "Aggregation and Linear Programming." Unpublished paper. Food and Resource Econ. Dep., University of Florida, 1979.

Takayama, T., and G. G. Judge. *Spatial and Temporal Price and Allocation Models.* Amsterdam: North-Holland Publishing Co., 1971.

Consideration of Investment Tax Credit in a Multiperiod Mathematical Programming Model of Farm Growth

Donald W. Reid, Wesley N. Musser, and Neil R. Martin, Jr.

Marginal federal income tax rates on farm firms have been increasing due to higher taxable incomes from increasing farm size, increasing off-farm income of farm families, and inflation. Krause and Shapiro and Barry (p. 29) have noted that agricultural economics research on the impact of these increased taxes is limited. The investment tax credit is a provision of federal income tax law that has received especially limited research attention. Kay and Rister analyzed the impact of this provision on beef cattle replacement, and Chisholm considered its impact on farm machinery decisions. However, the investment tax credit has not been considered in mathematical programming models of farm firm growth in the same manner as other income tax provisions (Vandeputte and Baker, Barry and Willmann). The purpose of this paper is to present a method of incorporating investment tax credit provisions in a multiperiod mathematical programming model. Specific objectives include: review of the theory of capital budgeting in reference to the investment tax credit, consideration of a tax submatrix for a programming model which includes investment tax credit, and presentation of an empirical example.

The Investment Tax Credit and the Theory of Capital Budgeting

In presentation of the theory of capital budgeting, agricultural economists generally follow Hirshleifer in utilization of a net present value framework (Baker, Chisholm, and Hopkin, Barry, Baker). In use of the present value framework, agricultural economists have not been sufficiently aware of its empirical weaknesses when capital rationing limits the capital budget. Hirshleifer noted in this situation that the theoretically correct discount rate was the marginal productivity of financial capital, which cannot be determined until the optimal capital budget is delineated (pp. 452–58). Because the investment of most farm firms is limited to internally generated equity funds plus the debt that can be obtained with this equity given conventional leverage positions, capital rationing could be relevant for many farm situations. Unfortunately, the issue of an empirically relevant discount rate under capital rationing has not been satisfactorily resolved (Baumol and Quandt; Burton and Damon; Mao, pp. 226–40; and Weston and Brigham, pp. 291–304). Beranek notes that one solution is to maximize accumulated wealth at the end of a planning horizon in a mathematical programming framework (p. 139). Boussard has justified this viewpoint in a farm firm growth research context. Weston and Brigham recommend the use of an internal rate-of-return formulation as a reasonable approximation under capital rationing (p. 283); their viewpoint is adopted in this section.

The theory of capital budgeting for a single period with an internal rate-of-return concept can be summarized in three equations:

$$(1) \qquad \sum_t \frac{R_{it}}{(1 + r_i)t} - (C_i - IT_i) = 0,$$

$$(2) \qquad r_i \geq k, \text{ and}$$

$$(3) \qquad \sum_i (C_i - IT_i) \leq B,$$

where R_{it} is future net cash flows from project i in year t, C_i is initial investment cost of project i at $t = 0$, r_i is the internal rate of return of project i, k is the cost of capital for the firm, IT_i is the investment tax credit for project i, and B is the maximum size of the capital budget. Equations (1) and (2) refer to the ith individual project available for investment in a particular period, while equation (3) is concerned with the total investment costs of all projects in this time period. With no financial constraints, B is infinite, and equation (3) is irrelevant to the capital-budgeting process. In this case, a project is included in the capital budget if its r_i, as determined by equation (1), satisfies equation (2).

If B has a finite value, two different cases of capital rationing are possible. In the first, the sum of net investment cost, which is $C_i - IT_i$, for all projects satisfying equation (2) is less than B, and equation (3) is not restrictive. In the second case, investment in all projects in which (2) holds causes (3) to be violated, and capital rationing is effective in restricting investment. The capital budget then includes projects in order of their r_i until (3) becomes restrictive.

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The impact of the investment tax credit on the capital-budgeting process arises from its reduction of net investment cost in (1) and (3). The most apparent effect is that r_i is raised in (1) with an investment tax credit and, therefore, potentially more projects meet (2) than without a credit. If B is nonrestrictive, the number of projects, and therefore the size of the capital budget, will be increased. When B is restrictive, this increase in r_i cannot increase the size of the capital budget but can change its composition if the r_i increase at different rates and the ranking is altered. However, the size of the capital budget also can increase because $(C_i - IT_i)$ is reduced for each project which qualifies for an investment tax credit and more projects can be undertaken.

Methods

In considering the effect of the investment tax credit in the capital-budgeting process, one approach would be to reduce the cost of qualifying investments by the amount of the investment tax credit to reflect net investment cost. However, the investment tax credit can be claimed only if an offsetting income tax liability exists. If low prices or yields result in low or zero tax liability, the investment tax credit has little or no effect on net investment cost. Even in normal years, a large investment in machinery, grain storage facilities, or livestock equipment could result in the investment tax credit exceeding the income tax liability in the year of the investment. Thus, a method of relating investment tax credit to income tax liabilities in both the year of the investment and other years is necessary to assess accurately the effects of the investment tax credit on investment.

A method of incorporating the investment tax credit into a multiperiod mathematical-programming investment model is illustrated in table 1. Part of the income tax activities associated with the nth period, along with production and investment activities linked with the tax activities, are included in this table. Activities *T1n*, *T2n*, . . . , *Tkn*, and rows *TICn* and *PTCn* reflect increasing marginal income tax rates according to Vandeputte and Baker's methods. *MTn* is added to provide for income tax payments on adjusted gross income in the highest tax bracket. *IAn*, *PAn*, and *MAn* are representative investment, production, and marketing activities, respectively, which affect income tax liabilities. Their effects on adjusted gross taxable income are reflected in the *TICn* row—*IAn* results in depreciation equal to A_d, *PAn* has production expenses equal to A_c, and *MAn* has gross revenues of A_r. The remainder of the submatrix involves the investment tax credit. (See also *U.S. Master Tax Guide, 1976*, pp. 431–33).

The basic provision of the investment tax credit—one dollar of tax reduction for each dollar of investment credit—is provided by the *BITCn* activity. Qualifying investment activities, *IAn* provide investment tax credits equal to A_c in the *ITCn* and *ITCYLn* rows. *BITCn*, in turn, uses these investment tax credits with entries in *ITCn* and *ITCYLn*. The tax savings in the subsequent period is reflected in the entry in the *OCA*(n + 1) row for *BITCn*. The amount of base investment tax credit is limited by two other constraints. *EITCLn*, which has entries for investment tax credits and income tax liabilities, limits the investment tax credit to the income tax liability. The base investment tax credit also is limited to a legal maximum B, which was \$25,000 in 1975, with *BITCLn*.

For situations in which the tax liability and investment tax credit earned are greater than the legal maximum, the extra investment tax credit provisions are appropriate. Under 1975 rules, this provision is that one dollar of tax liability results in a half-dollar of tax credit. Activities such as *EITCn* model this provision. The structure of this activity is similar to *BITCn* except that each unit of income tax liability in *EITCLn* allows A_a (.5 in 1975) in investment tax credit in *ITCn*, *ITCYLn*, and *OCA*(n + 1).

In situations in which the current investment tax credit is greater than current income tax liability, the tax credits can be carried back three periods and forward seven years under 1975 rules. These linkages with other periods are provided by *XITCBLnn* and *XITELnn* activities. The carry-back rule is appropriate when investment tax credit is greater than income tax liability in the current period, while income tax liability greater than tax credits existed in previous years. Activity *XITCBLn*(n − 3) which carries current tax credits back three years is an example of the carry-back transfers. The structure of this activity is similar to *BITCn* except that *BITCL*(n − 3) and *EITCL*(n − 3) replace analogous rows for the current period.

If income tax liabilities in carry-back periods are inadequate to exhaust excess earned investment tax credits in the current periods, the carry-forward provisions are appropriate. Activities *XITCBLn*(n + 1), *XITCBLn*(n + 7), and *XITELn*(n + 7) represent carry-forward activities from the current period. These activities use the tax credits provided in the current period, represented by entries in *ITCn* and *ITCYLn*, and supply credits to future periods with entries in *ITC*(n + 1) or *ITC*(n + 2). The cash flows arising from these credits will be reflected in operating capital rows for future periods.

If earned investment tax credits are greater than income tax liabilities in previous periods and less income tax liabilities in the current period, investment tax credits can be transferred forward to the current period. Activities *XITBL*(n − 7)n transfer earned investment from previous periods forward to the current period with entries in *ITC*(n − 7), *ITCYL*(n − 7), and *ITCn*. Activities such as *BITCXn* and *EITCXn* utilize investment tax credit carried forward to the current period and have a

Table 1. Submatrix of Tax Activities in Multiperiod Linear Program

	Base Investment Tax Credit		Transfer Base Investment Tax Credit				Extra Investment Tax Credit	
	Earned in Year n ($BITCn$)	Transferred to Year n ($BITCXn$)	Yr. n to $n-3$ ...	Yr. $n-7$ to n ...	Yr. n to $n+1$ ...	Yr. n to $n+7$ ($XITCBLnn$)	Earned in Year n ($EITCn$)	Transferred to Year n ($EITCXnn$)
Base investment tax credit limit in year: ($BITCLn$)								
$n-3$			1					
⋮								
n	1	1						
Additional investment tax credit in year: ($EITCLn$)								
$n-3$			1					
⋮								
$n-1$								
n	1	1					1	1
Investment tax credit constraint in year: ($ITCn$)								
$n-7$				1				
⋮								
n	1	1	1	−1	1	1	A_n	A_n
$n+1$					−1			
⋮								
$n+7$						−1		
Investment tax credit transfer in year: ($ITCYLn$)								
$n-7$				1				
⋮								
n	1		1		1	1	A_n	
Taxable income constraint in year: ($TICn$)								
n								
Progressive tax constraint in year: ($PTCn$)								
n								
Operating capital period J in year: ($OCAn$)								
$n+1$	$-A_n$	$-A_n$	$-A_n$				$-A_n$	$-A_n$

structure similar to *BITCn* and *EITCn* except for no entry in *ITCYLn*.

The transfer activities affect *ITC* and *ITCYL* rows asymmetrically. The function of *ITCYL* rows are to constrain the investment credit either claimed in the current year or transferred to another year to the amount of credit earned from current investments. Thus, activities claiming current credits (*BITCn* and *EITCn*) and activities transferring credits $XITCBLn(n-3)$, $XITCELn(n-3)$, and $XITCn(n+1)$ have entries in *ITCYLn*. The *ITC* rows have the function of constraining tax credits claimed in the current year to that available from current investments and transfers from other years. Thus, transfer activities such as $XITC(n-7)n$ and $XITCn(n+1)$ have negative entries in the $ITC(n-7)$ and *ITCn* rows, respectively. Also, activities that claimed transferred credits, such as *BITCXn* and *EITCXn*, have entries in the *ITCn* row but not the *ITCYLn* row.

A final feature of the investment tax-credit model structure is that small numbers must be added to the entries in the cash row *OCAn*. The magnitude of each entry establishes the priority in which the tax credit is taken while having a negligible effect on cash earned from the credit. For example, the legal priority is established by adding to the usual entry in *OCAn*, .009 for *BITCn*, .007 for *BICXKn*, and .005 for $XITCBLn(n-3)$.

Results

This study utilized a standard, multiperiod, linear programming model which represented a 462-acre farm in the Georgia Piedmont with 164 acres of cropland. The land was fully owned. Resident labor of 2,500 annual hours was available to be utilized either for labor or management of hired labor subject to a managerial constraint of 25,000 hours of hired labor. At the beginning of the planning horizon, a complement of crop machinery for production of corn and soybeans was available. Purchase or rental of additional land was not allowed so that firm expansion was limited to hog enterprises. Starting with zero debt, the firm was allowed to

	Transfer Extra Investment Tax Credit		Taxpaying Activities in Year n				Investment Activity in Year n	Production Activity in Year n	Marketing Activity in Year n	
	Yr. n to $n-3$ . . .	Yr. n to $n+7$ (*XITELnn*)	Tax Bracket 1 (*T1n*)	2 . . . (*T2n*)	k (*Tkn*)	Max Tax (*MTn*)	(*IAn*)	(*PAn*)	(*MAn*)	*RHS*
Base investment tax credit limit in year: (*BITCLn*)										
$n-3$										$\leq B$
⋮										
n										$\leq B$
Additional investment tax credit in year: (*EITCLn*)										
$n-3$	1									≤ 0
⋮										
$n-1$										≤ 0
n			$-A_t$ . . .	$-A_t$	$-A_t$					≤ 0
Investment tax credit constraint in year: (*ITCn*)										
$n-7$										≤ 0
⋮										
n	A_a	A_a					$-A_c$			≤ 0
$n+1$										≤ 0
⋮										
$n+7$		$-A_a$								≤ 0
Investment tax credit transfer in year: (*ITCYLn*)										
$n-7$										≤ 0
⋮										
n	A_n	A_a					$-A_c$			≤ 0
Taxable income constraint in year: (*TICn*)										
n			A_y	A_y . . .	A_y	A_y	A_d	A_r	$-A_t$	≤ 0
Progressive tax constraint in year: (*PTCn*)										
n			1	1 . . .	1					$= 1$
Operating capital period J in year: (*OCAn*)										
$n+1$	$-A_o$				A_t . . .	A_t	A_t			≤ 0

Note: A_o is operating capital; A_a is additional credit; A_t, tax; A_y, income; A_c, tax credit; A_d, depreciation; A_e, cash expense; and A_r, cash receipt. Dots indicate missing actitivies.

incur debt during the ten-year period up to 30% of the value of its total assets. A fixed amount of $18,000 consumption withdrawal was assumed for the subject and was augmented at an annual rate of 5% to accommodate inflation. Other prices, costs, and asset values also were subjected to trends with the hog price trends including price cycles (Reid). The objective function of the model was to maximize net worth at the end of the planning horizon. Net worth at the end of the planning horizon reflected value of assets before liquidation (Reid, Musser, Martin).

A summary of the solutions from the model with and without an investment tax credit are presented in table 2. These results indicate that the investment tax credit stimulated firm growth as measured by several criteria (LaDue). In terms of net worth, the solution with an investment tax credit had a higher value in all years than the solution without an investment tax credit. In the final year, net worth was $1,165,809 with a credit and $1,043,945 without. In terms of annual net cash income before taxes, approximated by adjusted gross taxable income, the situation with investment credit was generally higher except for 1975 and 1985. In 1975 the after-tax cash income was higher with an investment tax credit, $30,459 compared to $28,734, and low hog prices resulted in zero taxable income in both situations in 1985 (Reid). In terms of physical output, crop output was the same in both situations. However, more expansion occurred in hog production with the credit; for example, in 1983, 70,767 hundredweight of hogs were sold compared to 50,429 hundredweight without a credit. It can be noted that the largest relative impact of the investment tax credit was on physical production rather than net income or net worth. This result suggests that the investment tax credit benefits consumers of agricultural products more than agricultural producers even at the microlevel.

Table 2. Impact of Investment Tax Credit on Growth Pattern of a Model Farm in the Georgia Piedmont, Selected Years 1975–85

Item	Unit	1975	1980	1983	1985
With investment tax credit:					
Net worth	$	279,321	918,665	1,130,743	1,165,809
Adjusted gross income	$	33,600	199,041	164,839	0
Gross federal taxes	$	7,100	106,454	83,078	0
Investment tax credit	$	3,959	7,066	11,518	2,216
Hired labor	hr.	0	9,874	13,028	0
Market hogs sold	cwt.	3,667	56,396	70,767	1,385
Dual value for long-term security	$	.756	.063	0	.020
Without investment tax credit:					
Net worth	$	274,242	844,779	999,006	1,043,945
Adjusted gross income	$	37,263	176,741	113,402	0
Gross federal tax	$	8,529	91,156	50,017	0
Hired labor	hr.	0	8,585	8,632	0
Market hogs sold	cwt.	3,667	50,429	50,429	1,385
Dual value for long-term debt security	$	.630	.048	0	0

In understanding the process of increased growth with an investment tax credit, it is necessary to consider the investment processes in the two situations. First, the investment process limited expansion in both situations; at maximum hog production during the planning horizon of 70,767 hundredweight of hogs in 1983, hired labor was 13,249 hours, which was well below the managerial constraint level of 25,000 hours. An additional dimension of the investment process is that B in equation (3) is finite because additional equity capital is limited to retained earnings. Furthermore, positive dual values for the long-term debt security restriction in most years indicated that the capital budget constraint was effective in most years. In these years, additional investment with an investment tax credit arises from the influence of lower net investment cost with the tax credit. This lower investment cost is reflected in a greater investment in market hog facilities in 1976–80; the increase in market hog production, which requires these facilities, is greater in each of these years with an investment tax credit.

The effect of the investment tax credit without effective capital rationing is apparent in 1983. In that year, market hog facilities were increased from the 56,396 hundredweight capacity in 1980–82 to 70,767 hundredweight; however, the capacity was maintained at its former level of 50,429 hundredweight without an investment tax credit. Evidently, the existence of the investment tax credit raised the internal rate of return on additional market hog facilities in 1983 to a level above the cost of capital so that equation (2) is met.

The results also allow an evaluation of the necessity to incorporate investment tax credit provisions into the tax submatrix. For this farm situation, investment tax credit was always less than income tax liability except for 1985. In that year, a tax credit of $2,216 was earned on the investment in feeder pig facilities for the expansion of feeder pig production from 13- to 87-sow units. For this year, the model carried $553 of the credit back to 1982 [$XITCBLn(n-3) = 553$] and $1663 back to 1983 [$XITCBLn(n-2) = 1{,}663$]. These activity levels were consistent with the requirement to carry back three years having the highest priority; the income tax liability in 1982 was not sufficient to exhaust the credit, so that the remainder was carried back two years to 1983. It must be stressed that the cash flows generated from the tax credit would be available when income tax returns were filed in this carry-back situation. Thus, sufficient current and carry-back income tax liabilities existed in the model so that investment tax credits could be claimed in the year earned. However, direct adjustment of the cost of capital investments to reflect the investment tax credit would not have reflected the lag of one period between investment and receipt of the tax credit that results from annual tax-filing requirements in farming. The direct method would have accelerated the actual impact of the credit. The same production of 3,667 hundredweight of hogs in the initial period in both situations illustrates the lag in receiving the investment tax credit. Thus, the adjustment of investment costs could have approximated the impact of tax credits in this model but would have overstated its impact on the investment process.

These results concerning inclusion of investment tax credit in multiperiod investment models can be generalized to other farm situations. The condition that sufficient tax liabilities exist in the current and preceding three years, to allow claiming the credit in the current period, does not seem stringent even considering the variability of agricultural production and prices. Only if this condition is likely to be violated would inclusion of investment tax submatrices significantly improve the approximation of the investment process. Such situations include a se-

quence of years with low profits, such as 1985 in the model in this paper, and/or periodic large investments in the model.

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References

Baker, C. B. "Capital Budgeting and Financial Management in Linear Programming Models." *Studies in Economic Planning over Space and Time*, ed. George G. Judge and Takashi Takayama. New York: American Elsevier Publishing Co., 1973.

Barry, Peter J. "Strategies for Growth." *Economic Growth of the Agricultural Firm*. Washington State University Agr. Exp. Sta. Tech. Bull. 86, Feb. 1977.

Barry, P. J., and D. R. Willmann. "A Risk Programming Analysis of Forward Contracting with Credit Constraints." *Amer. J. Agr. Econ.* 58(1976):62–70.

Baumol, William J., and Richard E. Quandt. "Investment and Discount Rates under Capital Budgeting—A Programming Approach." *Econ. J.* 75(1965):317–29.

Beranek, William. *Analysis for Financial Decisions*. Homewood, Ill.: Richard D. Irwin, 1963.

Boussard, J. M. "Time Horizon, Objective Function, and Uncertainty in a Multiperiod Model of Firm Growth." *Amer. J. Agr. Econ.* 53(1971):467–577.

Burton, R. M., and W. W. Damon. "On the Existence of a Cost of Capital under Pure Capital Rationing." *J. Finan.* 29(1974):1165-73.

Chisholm, A. H. "Effects of Tax Depreciation Policy and Investment Incentives on Optimal Equipment Replacement Decisions." *Amer. J. Agr. Econ.* 56(1974):776–83.

Hirshleifer, J. "On the Theory of Optimal Investment Decision." *J. Polit. Econ.* 66(1958):329–52.

Hopkin, J. A., P. J. Barry, and C. B. Baker. *Financial Management in Agriculture*. Danville, Ill.: Interstate Publishers, 1973.

Kay, Ronald D., and Edward Rister. "Income Tax Effects on Beef Cow Replacement Strategy." *S. J. Agr. Econ.* 9(1977):169–73.

Krause, Kenneth R., and Harvey Shapiro. "Tax-Induced Investment in Agriculture: Gaps in Research." *Agr. Econ. Res.* 26(1974):13–21.

LaDue, Eddy L. "Toward a More Meaningful Measure of Firm Growth." *Amer. J. Agr. Econ.* 59(1977):210–15.

Mao, James C. T. *Quantitative Analysis of Financial Decisions*. New York: Macmillan Co., 1969.

Reid, Donald W. "A Multiperiod Analysis of Intensive Farm-Firm Growth in the Georgia Piedmont." M.S. thesis, University of Georgia, 1978.

Reid, Donald W., Wesley N. Musser, and Neil R. Martin, Jr. "Income Tax Aspects of Liquidation in Multiperiod Linear Growth Models." *S. J. Agr. Econ.* 10(1978):29–34.

U.S. Master Tax Guide, 1976. Chicago: Commerce Clearing House, 1975.

Vandeputte, J. M., and C. B. Baker. "Specifying the Allocation of Income among Taxes, Consumption, and Savings in Linear Programming Models." *Amer. J. Agr. Econ.* 52(1970):521–27.

Weston, J. Fred, and Eugene F. Brigham. *Managerial Finance*, 5th ed. Hinsdale, Ill.: Dryden Press, 1975.

A Routing Algorithm Using the Nearest Neighbor Concept: Comment

J. W. Hubbard

Hallberg and Kriebel have demonstrated that utilization of the nearest neighbor concept may save unnecessary backtracking and will minimize distance traveled in servicing product delivery or assembly routes. The Hallberg-Kriebel illustration of an optimum route included one unit of backtracking travel, however, and required sixteen units of travel to service fourteen customers (their fig. 2).

For cases of this kind in which management can influence the layout of the territories to be covered, it easily can be demonstrated that routes can be designed so that nearest neighbor servicing results in no backtracking. All that is required is that the rectangular grid to be serviced have an odd number of blocks in at least one direction. Under the customer location conditions assumed by Hallberg and Kriebel, the number of units of travel will be one greater than the number of customers serviced, if the grid has at least one dimension in which the number of blocks is odd. An optimum route for a grid two blocks in one direction and five blocks in the other direction is illustrated, figure 1. Note that the warehouse could be located at any intersection on the grid without affecting the distance to be traveled. Placing the warehouse at a corner of the grid would permit servicing four similar territories from one warehouse with no backtracking on any route. Grids with an even number of blocks in both directions will require backtracking irrespective of the location of the warehouse. Under the Hallberg-Kriebel assumption as to customer location, an optimum route of travel results in one unit of backtracking on a grid with an even number of blocks in both directions and no backtracking on a grid with an odd number of blocks in at least one direction. For an optimum route, the number of units of travel will be one greater than the number of customers serviced, if the grid has an odd number of blocks in one direction; it will be two greater than the number of customers serviced, if the grid has an even number of blocks in both directions.

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Reference

Hallberg, M. C., and W. R. Kriebel. "A Routing Algorithm Using the Nearest Neighbor Concept." *Amer. J. Agr. Econ.* 61(1979):87–90.

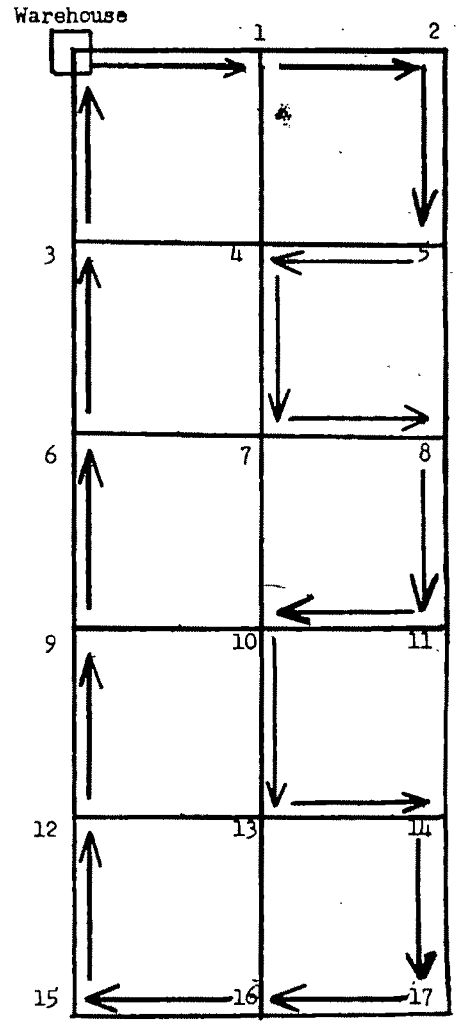

Figure 1. No backtracking nearest-neighbor solution to hypothetical routing problem

Publications

Books Reviewed

Abrahamsen, Martin A. *Cooperative Business Enterprise*. New York: McGraw-Hill Book Co., 1976, xix + 491 pp., price unknown.

This book takes a descriptive-historical-institutional approach to the subject of cooperative enterprise. Most of the information in the book is condensed from a plethora of publications on cooperatives, with limited original analysis conducted by the author. A heavy reliance on Farmer Cooperative Service publications may be explained by the author's many years of service with that agency.

The first nine chapters primarily are devoted to defining cooperatives and to placing their development in historical perspective. Seven definitions of cooperative enterprise from other sources are reviewed, and from these definitions the author derives seven "basic features" of cooperative business enterprise (as distinguished from the general concept of cooperation). Full chapters are devoted to listing types of cooperatives and to charting the historical development of cooperative principles. Chapter 4, which lists many contributors to cooperative theory, carries an orientation common to the entire book: long on history and short on economic analysis. Some recent, rigorous contributions to cooperative thought are mentioned only briefly or are relegated to footnotes (pp. 81–85).

Chapter 10, "Special Legal Problems," contains a useful summary of important court decisions affecting the structure and operations of U.S. agricultural cooperatives. An instructor using this book will need to update the text material with recent court decisions and changes in important legislation, e.g., USDA regulations pertaining to Section 2 of the Capper-Volstead Act.

The author states that there is "much confusion and misunderstanding" about the topic discussed in chapter 11: "Cooperative Taxation;" the information presented in this chapter should help the noninitiated reader better understand this topic. However, less description of legislative and case history of cooperative taxation, and more discussion of contemporary tax issues—including those identified on pp. 241–2—would have strengthened this part of the textbook.

Approximately 30% of the book deals with cooperative management topics, including organization, communication, finance, bargaining, mergers, and liquidation. While the student unexposed to (cooperative or noncooperative) management principles and practices may gain some insight from these chapters, the book patently does not qualify as a "how to" management primer. If management topics are a major emphasis in a course on cooperatives, the instructor would be well-advised to select another text, or to supplement this book heavily with other teaching materials, as recommended in the preface.

The author characterizes his book as "a basic college and university text" to "improve . . . teaching of cooperative enterprise" (p. xv). The reviewer's experience teaching these topics leads him to conclude that the text includes material of interest to lower-division college and high school students of cooperation. However, this book should not be used as the sole reading reference, and its paucity of analytical economic content will limit its usefulness in upper-division and graduate-level university courses.

James G. Youde
Northwest Economic Associates

Cramer, Gail L., and Clarence W. Jensen. *Agricultural Economics and Agribusiness: An Introduction*. New York: John Wiley & Sons, 1979, 440 pp., $18.95.

This textbook is designed to be used in an introductory agricultural economics or agricultural business course. It is well done and deserves serious consideration by teachers wanting an analytical approach to agricultural economics.

The book contains the microeconomic principles included in many introductory courses in an analytical but easy to understand way. After an introduction which gives a student a good overview of American agriculture, it contains a discussion of supply, demand, and price determination; factor-factor, factor-product, and product-product decision making; and a discussion of competitive structure and marketing. These topics would provide the basis for most introductory courses. In addition to this basic material, a wealth of additional topics is covered in the last part of the book, some, but not all of which, will be chosen by teachers for their students depending on their own interests. These topics include discussions of agricultural finance, natural resource use, agricultural price and income policy, international trade, population-food balance, world development, and a particularly interesting section on comparative agricultural systems, focusing on the USSR and China.

This text provides a sound basis for teaching microprinciples in a beginning agricultural economics course. It contains more detail and more topics than most teachers would want to use. However, it is well designed so that the teacher really has no problem in sorting among those things which he chooses to emphasize with his students. The presentations are clear and accurate and the text is refreshingly brief. The text is sprinkled with many

diagrams and tables of factual information, most of which are complete through 1976 and 1977.

Students will like this textbook because it is short, easy to read, particularly clear, and it presents information in an organized way. They will like the summary at the end of each chapter and will appreciate particularly the very brief enumeration of the major points made in each chapter under "chapter highlights." They will like the ready access to a great deal of data describing American agriculture and the wide variety of topics available to them to study.

Teachers will like this textbook because the presentation is clear, concise, and accurate. They will appreciate the wide range of topics in the later part of the book from which to choose to add spice and character to the course.

If this text has a weakness, it is that it puts considerable emphasis on economic theory and the teacher and student looking for ideas to apply today may feel some frustration with it. However, as we teach today, preparing students for the year 2015, it is the theory which will continue to be useful. I agree with the emphasis that the authors have used in this text.

The authors are to be commended for putting together an excellent textbook that can meet the needs of a wide variety of teachers and students of agricultural economics.

Robert W. Taylor
Purdue University

Hayami, Y., in association with M. Kikuchi, P. F. Moya, L. M. Mambo, and E. B. Marciano. ***Anatomy of a Peasant Economy: A Rice Village in the Philippines.*** **Los Banos, Laguna, Philippines: The International Rice Research Institute, 1978, xi + 149 pp., price unknown.**

This intensive case study of a typical rice village in the Philippines deals broadly with the impact of new rice technology and improved irrigation on rural welfare. The study is based on a recognition that the dichotomy of production and investment functions of firms and consumption and savings functions of households typical in the urban sector does not hold in the peasant sector. The economic behavior of the peasant sector must, therefore, be understood in terms of the merging into one within individual peasant households of these four functions. Further, because "to a large extent the village community in developing countries is self-contained" (p. 1), a study of the peasant economy must also involve an examination of the interactions among households within the village, and the role of the village within the overall economy.

To enable an understanding of the complex interactions among economic activities within a household and within a village, data on production, consumption, investment, and transaction activities were collected daily over one year from eleven of ninety-five households residing in Barrio (village) Tubuan, Laguna Province. The data, recorded on seven completely articulated accounts based on the United Nations System of National Accounts, covered current rice, nonrice, and nonagricultural production; income-expenditures; fixed-capital production; capital finance; and transactions. The village social account reflected the aggregate-total of the private economic accounts for individual households in the village, minus transactions and financial claims among households within the village, and plus (*a*) government infrastructure subsidies and (*b*) the stock values of community capital.

The analysis of the village accounts—which in the reviewer's judgment clearly represents the most novel feature of this study—shows that (*a*) the incomes of village dwellers are derived almost exclusively (96%) from agricultural production within the village, with rice dominating by more than four times the other two agricultural enterprises, ducks and pigs; (*b*) of total village output, 58% was paid to village-owned factors, 21% to absentee landlords, 16% to current inputs, and 5% to feed and seed; and (*c*) more than one-half of disposable income was spent on consumer goods from outside the village, about one-third on village-produced consumption, and the balance was saved. The authors tentatively conclude that (*a*) future increases in villager income will have to come from increased rice productivity and/or expanded nonland-based enterprises; (*b*) the substantial supply of unused labor during the off-season months of rice farming could be used to form output-increasing community capital such as irrigation and drainage facilities, fences, and terraces; and (*c*) the current rather heavy reliance of the village on outside consumer goods could be reduced if villagers would expand home garden vegetable production and/or cottage industries.

The authors state that their study "represents an experiment in data collection and documentation for the analysis of the village economy in its whole complexity" (p. 110). *Anatomy of a Peasant Economy* communicates comprehensively the results of this experiment. Its seven accounts and the analysis of the data within them, at the level of both the individual household and the village, are shown clearly. While the accounts omit attention to household chores such as child rearing, cooking, and sweeping—and, therefore, are less complete than what is covered in the *New Household Economics* (deTray)—the authors go beyond conventional treatments in that they base their household and village accounts on a framework of macro-national accounts and deal explicitly with village-level flows of goods and services. Within this perspective, the book will undoubtedly appeal to many micro-oriented members of the research community.

The suggestion that the authors' approach, "if applied to various sites over time, will provide a solid data base for advancing the theory of the

peasant economy as well as for formulating rural and national development policy" (p. 111), in the judgment of the reviewer, however, is considerably more problematic.

In their introduction, the authors cite earlier theoretical and empirical studies of the peasant economy (though they omit attention to Wharton's classical collection of readings on *Subsistence Agriculture and Economic Development*), but indicate that "a serious constraint on the theoretical developments has been a lack of a systematic collection of data amenable to the analysis of the peasant complex" (p. 2). Whereas they proceed to collect a systematic set of apparently relevant data, they make no attempt to utilize their empirical findings to further develop the theory of the peasant economy. Whether their approach can be expected to contribute to the advancement of theory is, therefore, as yet untested.

In their introduction, the authors also state that their planned household-village accounting should provide "the basis for (the more) effective design of rural development programs and national development policy" (p. 2). While on the surface such a proposition has intuitive appeal, further reflection raises some troublesome questions.

Consider first the nature of the illustrative case treated in the book. The village studied is described as a "typical rice village in the Philippines" (p. ix), yet its yields and double-cropping ratio are 65% and 20%, respectively, above the national averages (p. 11), and its population growth rate is almost 40% above the national average (p. 14). The respondents were selected on the basis of their expected ability and willingness to participate in the project, not randomly (p. 4). The some 100 tables and figures in the book, therefore, are based on data from only 11 nonrandomly selected households in a village which in no substantive way can be said to represent all Philippine rice villages.

What can be concluded about national development policies from such a study? Probably not much, as the authors acknowledge in their conclusion: ". . . any generalizations from the data could be hazardous. . . . The tentative policy implications that we have drawn from the experimental study should . . . be taken with great caution" (pp. 110, 11).

What are the possibilities for future studies to overcome the *Anatomy*'s inability to generate policy conclusions? The reviewer concludes that the possibilities are remote. The suggested approach is simply too data-intensive to be relied upon as the primary source of insights for national policy making. While the authors do not indicate the financial resources required to undertake their study, one can imagine that they must have been considerable. Human limitations are probably even more critical. What proportion of Asian rice farmers could be expected to maintain the detailed daily records used in this study? How many researchers would be willing to cope with the massive detail required to manage and supervise the collection and analysis of such a large data-set as that involved in the *Anatomy*? Even if financial and human resources adequate to replicate such a study several times could be mustered, might the payoff to society from using part of these resources in less data-intensive research approaches be greater?

While these questions cannot be answered definitively, the reviewer concludes that the *Anatomy* methodology should be looked upon as but one of several that may be used by policy-oriented social scientists. Within this perspective, he believes that the economic development profession should be indebted to the authors for contributing, via the *Anatomy*, to our analytic capacity to deal with rural development problems.

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References

deTray, Dennis N. *Household Studies Workshop*. New York: Agricultural Development Council Rep. No. 13, May 1977.

Wharton, Clifton R., Jr., ed. *Subsistence Agriculture and Economic Development*. Chicago: Aldine Publishing Co., 1969.

Leuthold, Raymond M., ed. *Commodity Markets and Futures Prices*. Chicago, Chicago Mercantile Exchange, 1979, 279 pp., $4.00 paper.

George Croly once asked a reviewer if he had read the book he was reviewing. When the reply was yes, Croly responded, "That's wrong, it creates a prejudice" (Challenge).

This reviewer approached the book at hand with much the same attitude. Two salutary characteristics would seem to make it a worthy work with no further prejudice needed. That is, it stimulates professional discussion by providing a compilation of current research projects, and it explores a subject area which has received too little recent professional attention: the commodity futures markets. The result should not disappoint those wishing to sample a reasonable collection of current research topics and techniques in this subject field.

Eleven papers were selected by the editors and organized into sections on "Price Behavior," "Forward-Pricing Efficiency," "Financial Implications of Hedging," and "Price Relationships." All were drawn from the Fellowships in Futures program started in 1970 by the Chicago Mercantile Exchange. All empirical tests are performed on the commodities traded on that exchange ranging from pork bellies to international money market instruments.

The selection is well-edited, with introductory comments to each major section briefly summarizing the works to follow. In addition, the editor links each paper with the existing literature in the field.

Since the papers were not written with publication in this form in mind, this is an extremely helpful feature.

The works selected for this volume vary tremendously in their sophistication and their focus. They range from specific tests of single behavioral aspects to exploration of a technique which might be used to identify imminent exchange rate revaluations in the international currency market. The selections are too broad for a summary of conclusions here.

A few words may be said, however, about the most interesting portion of the collection: section 4, which deals with price relationships. The three papers included under that heading touch on many fundamental features of the futures markets that have strong policy implications. Although not intended to draw the implications to their fullest, the works deal with the impact of location basis variability on hedging programs, the impact of temporal allocation of seasonal inventories on the inventory adjustment process, and the impact of information flows on market performance. Those following the current policy debates will find this section of particular interest.

If these collected works, and indeed the Fellowships in Futures program are to be faulted, it is in the infrequency with which the fundamental questions pertaining to commodity futures markets are approached. It would be interesting, for example, to see a paper exploring an ongoing monitoring system to identify those contracts no longer functioning efficiently or a paper exploring the role of professional floor traders in establishing new contract markets or new exchanges.

On the whole though, the collected works are well worth reading and reflect favorably on a valuable research program. If the papers in section 4 are an indication of the trend in research sponsored by the CME Fellowships in Futures Committee, their second compilation of research volume should be well worth waiting for.

Tim Hammonds
Food Marketing Institute

Reference

Challenge, p. 3, July-Aug. 1979.

Witkowski, Edward, and Arnold Wells. *The Economics of Agricultural Production*. Sherman Oaks, Calif.: Alfred Publishing Co., 1979, xi + 231 pp., $14.95.

The authors attempt to provide a textbook for a course in agricultural production economics. They indicate in the preface that most textbooks on the subject are somewhat dated, emphasize institutional material, and obscure the theory. This book is supposed to serve as a teaching tool that emphasizes the method and process of economic decision making.

The book begins with a discussion of the production function, the costs of production, and the revenues from production. This discussion is followed by four chapters on decision making that cover factor-product, factor-factor, and product-product decisions. Finally, the last chapter is devoted to a cursory treatment of linear programming applied to agriculture. Each chapter is designed to provide (*a*) a verbal explanation, (*b*) a tabular example, and (*c*) a graphical depiction of the concept that the authors are attempting to illustrate. Simple questions at the end of each chapter serve as a useful check on the student's understanding of the concept that is presented.

Given the above structure, the book has two major shortcomings. The first pertains to the treatment of the material that is covered and the second to the material that is omitted. Although the expository style is generally adequate, the material contained in the book is wanting. The graphical analyses are repetitious, especially in chapter 6. The tabular examples appear to be based upon hypothetical data, meaningless units of measurement, and unrealistic production practices. These examples would be enhanced by actual experimental data, which would increase the book's credibility with students.

The authors ignore the difficult applications of the theory but indicate in the introduction that the purpose of the book is to aid the agricultural decision maker in a world of increasing complexity. Additional references to more advanced materials, or any other sources, are not provided for the interested student.

The inclusion of a chapter on linear-programming analysis has merit. Yet, the coverage is grossly inadequate. Unless the instructor develops substantial supporting material, this discussion of linear programming is only capable of confusing the student.

The topics that are not covered present a more serious shortcoming in a course concerned with modern commercial agricultural production. More specifically, the book ignores the following topics: (*a*) risk and uncertainty and the application of decision-theoretic analysis, (*b*) acquisition of factors of production and the associated capital investment decisions, (*c*) treatment of limited resource situation and the associated allocation decisions, (*d*) financial management and cash flow accounting, and (*e*) enterprise and partial budgeting analysis. Although avoiding institutional materials is a goal of the authors, they have succeeded in avoiding much additional material that would make the book relevant and interesting to students.

In summary, the book avoids many topics relevant to an undergraduate course in agricultural production economics and does not provide appropriate and concise illustrations for the topics that are covered. Thus the quest for a suitable text must continue.

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Institutional Members, 1979

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Beekeeping, Pollination, and Externalities in California Agriculture

John W. Siebert

Pesticide-induced beekills cost California beekeepers almost $1 million in 1975. California almond growers depend on bees for crop pollination and thus lost approximately $200,000 from beekills during this same year. A partial equilibrium framework is employed to calculate the marginal revenue product of a bee colony to the beekeeper and the marginal value product of a bee colony employed by an almond grower. The issue of bee protection is addressed in the context of the Tulare County citrus nectary. It is found that substantial net gains in total income were realized from the establishment of a bee protection area.

Key words: almonds, citrus, cost-benefit analysis, externalities, honeybees, pesticides, pollination.

California beekeepers earn a living through the production and sale of the multiple apiary products: honey, pollination service, and bees. These products are produced through a reliance on both commercial crops and natural forage. A serious problem arises when pesticide-induced beekills occur. Both beekeepers and growers of crops dependent on bees for pollination suffer financial losses. This article investigates such externalities from the viewpoints of the beekeeper who needs crops for honey production, the grower who needs bees for pollination, and the grower who uses pesticides and, in so doing, kills bees. Because of both the intractable nature of externalities and of weaknesses in certain data, the results obtained in this study should be considered exploratory.

To investigate growers who require pollination, almonds were selected because they have the highest total revenue of all California crops dependent on bees. Such revenue equalled $115 million in 1975. To investigate growers who use pesticides and, in so doing kill bees, citrus was selected because (*a*) bees are dependent upon citrus nectar for honey production, and (*b*) substantial beekills have occurred in citrus groves. With the exception of tangerines and tangelos, most citrus is not dependent on bees for pollination.

In what follows, a partial equilibrium framework will be developed and used to obtain estimates as to the external cost which pesticide-induced beekills impose upon beekeepers and upon almond growers. Then attention will be turned to the role of property rights. Recent property right reassignments in the Tulare County citrus nectary will be investigated through a cost-benefit framework similar to many of the empirical works surveyed by Mann. While almond growers and citrus growers face quite different production problems, the plight of the beekeeper serves as both the link between these problems and the reason for the focus of the study.

Background

Pesticides kill an 11% average of California's bees each year (Siebert). Still, there can be little doubt as to the importance of beekeeping in California. In 1975, more than $411 million dollars worth of crops depended on bees for pollination, while the beekeeping industry itself produced output valued at $22 million.

Economists (Meade, Cheung, and Johnson) have given substantial attention to the problem of bees and externalities. However, such

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work has not focused on pesticide problems. Instead, it has examined the market for honey forage land and/or pollination services when information may be imperfect. Cheung (p. 30) held that society's relevant beekill issue is "whether the gain from using the pesticide is greater than the associated loss of bees, in total and at the margin." However, he did not estimate the cost which pesticide externalities impose upon beekeepers or upon growers who use bees for pollination. Cheung did cite examples wherein beekeepers and growers have cooperated to reduce bee deaths. But the detailed specification of property rights was taken to be unimportant in determining the externality.

The Analytical Framework

Following the framework set out by Castle, consider a beekeeper with the revenue function $R = R(\bar{Z}, Z_2)$, where R is the total revenue from the sale of all apiary outputs, $\bar{Z}$ denotes a vector of inputs, and Z_2 denotes the beekeeper's peak colonies ($\partial R/\partial Z_2 > 0$). Also consider the production function of an almond grower who uses bees for pollination, $Y = Y(\bar{X}, X_3)$, where $\bar{X}$ denotes a vector of inputs to almond production and X_3 denotes the almond grower's use of bees for pollination ($\partial Y/\partial X_3 > 0$). Finally, consider the production function of a grower who does not need bees for pollination, $S = S(W_1, W_2)$, where W_1 denotes the use of pesticides and W_2 is another input. When pesticides are used, nearby bees often die: $\partial Z_2/\partial W_1 < 0$, and $\partial X_3/\partial W_1 < 0$.

The externalities analyzed in this article are the beekeeper-pesticide user externality, $(\partial R/\partial Z_2)(\partial Z_2/\partial W_1)$, and the pollination user-pesticide user externality, $(\partial Y/\partial X_3)(\partial X_3/\partial W_1)$. If these two externality effects are to be at efficient levels in terms of maximum social product; then, aside from the satisfaction of the total condition, it must be the case that the aggregate marginal benefit of pest control just equals the aggregate marginal cost to the pesticide users themselves plus the aggregate marginal external costs to beekeepers and those growers dependent on bees for pollination. While an estimate of the efficient level of pesticide use is beyond the scope of the present study, estimates of $\Sigma[(\partial R/\partial Z_2)(\partial Z_2/\partial W_1)]$ as summed over all beekeepers and $\Sigma[(\partial Y/\partial X_3)(\partial X_3/\partial W_1)]$ as summed over all growers are presented.

A Beekeeping Production Function

California beekeepers earn revenue from the sale of five different products: honey, beeswax, pollination, queen bees, and packaged bees. Although honey and beeswax are fixed coefficient outputs in relation to each other, when given a suitable environment the beekeeper can choose independently the relative quantities of the other outputs. To produce honey, the bees require access to plants with heavy nectar flows. To produce pollination, the bees must visit plant flowers and in so doing transfer pollen, thus causing those plants to bear more fruit than they would have otherwise. To produce queens, a laboratory-like process is followed whereby several queens are raised simultaneously. Finally, packaged bees (field bees raised by one beekeeper and sold to another) are produced by providing colonies with early season access to plant flowers with heavy pollen content.

The primary input of the beekeeping firm is the bee colony itself. Other significant inputs include labor, transportation equipment, bee food, and honey-processing facilities. Labor is important because (*a*) bee colonies grow and thus need frequent attention to insure that overcrowding does not exist, and (*b*) both transportation and honey extraction require labor. All beekeepers need transportation for their bees because no one small area contains a wide enough variety of forage for the entire year. Bee food and/or pasture are necessary to insure that the bees do not starve. The honey house and processing equipment are required to extract and package the honey crop.

To estimate a beekeeping production function, 1968 cross-section data on forty-eight California firms were obtained from Reed and Schneider (1976). Using these data the following Cobb-Douglas revenue function was estimated:[1]

$$R = \beta_0 Z_1^{\beta_1} Z_2^{\beta_2} Z_3^{\beta_3} e^u, \tag{1}$$

where R is the total revenue of the beekeeping firm from the sale of all outputs, Z_1 is the number of spring colonies, Z_2 is the number of peak colonies, Z_3 is the labor in man hours, and $u \sim n(0, \sigma^2)$. The results for log-linear estimation of (1) are shown in table 1.

It should be recognized that the revenue

[1] Managerial information for these beekeepers was not available; hence, the coefficient estimates may be biased. Klein (p. 212) discussed the assumptions which underlie specifications of this nature.

Table 1. OLS Estimation of a Cobb-Douglas Revenue Function for Beekeeping

$$\ln R = \underset{(0.5726)}{2.2272} + \underset{(0.1632)}{0.4837} \ln(Z_1) + \underset{(0.1236)}{0.3639} \ln(Z_2) + \underset{(0.1025)}{0.2860} \ln(Z_3)$$

$R^2 = 0.8552$ SSR $= 6.1343$

$n = 48$

Note: R is defined with 1975 prices while all output and input quantities are based on 1968 cross-section data. This was done because (*a*) only 1968 data were available and (*b*) the policy analysis which follows is for 1975. It is true that the above estimate for β_2 lies within the 95% confidence interval for β_2 when 1968 prices are used. However, some problems still exist in that 1968 was a poor year for honey production. The figures in parentheses are standard errors.

function shown in (1) does not conform with basic microeconomic theory. Such theory (Henderson and Quandt, p. 89) explains multiple output production as the result of profit maximization constrained by a concave production possibility frontier (*PPF*). Therefore, before estimating (1), Hasenkamp's Constant Elasticity of Transformation—Cobb-Douglas production function was estimated. However, the resultant *PPF* was convex to the origin, thus precluding the derivation of any supply or demand curves. Hence, the revenue function, rather than a multiproduct production function, was used to determine the financial effect of bee deaths.[2]

Beekeeping under Externality

Because most beekills occur in the summer months when the colony population is at its peak, the 1975 externality impact of pesticides on the entire beekeeping industry can be calculated in terms of the value of profit foregone,

$$K = \sum_{i=1}^{N} \left[\int_{Z_{i2}^0}^{Z_{i2}^1} (\partial R_i/\partial Z_{i2} + \partial C_i/\partial Z_{i2})\, dZ_{i2} \right],$$

where R_i is the total revenue earned by beekeeper i, C_i is beekeeper i's cost of replacing dead colonies, Z_{i2}^0 is the initial number of peak colonies owned by beekeeper i before pesticide damage, Z_{i2}^1 is the number after pesticide damage, and N is the total number of beekeepers in the California beekeeping industry. To facilitate estimation, K is simplified to

$$(2) \quad \hat{K} = [\text{mean } (\partial R_i/\partial Z_{i2}) + RCPC] \cdot (\Delta Z_2),$$

where mean $(\partial R_i/\partial Z_{i2}) = \dfrac{1}{48} \sum_{i=1}^{48} \left(\dfrac{\hat{\beta}_2 R_i}{Z_{i2}} \right) =$ \$10.78 is the change in total revenue with respect to a change in colony numbers. This figure is calculated over the sample of forty-eight beekeepers using the regression results in table 1. *RCPC* is the replacement cost per colony, which is \$20.38. This cost is set equal to the price of a queen bee (\$4.92) plus the cost of two pounds of bees (\$10.46) plus the labor cost for hive reconditioning (\$5.00). Finally, ΔZ_2 denotes total statewide bee deaths, or 31,000 colonies in 1975. The resultant estimate of damages is thus, $\hat{K} = \$31.16 \times 31{,}000 = \$965{,}960$.

An Almond Production Function

Almonds bloom in February and March, earlier than any other crop which requires bees for pollination. Cold, short days sharply reduce both the hours of bee flight and the receptiveness of flowers to pollination. To insure successful pollination, the employment of large and vigorous bee colonies is necessary (Sheesley and Poduska). Should colony damage occur during pollination, most likely from a neighbor's pesticide use, a substantial reduction in yield would result.

Because almonds are a perennial crop, rather than an annual crop, age of the plant is a crucial variable in determining yield. French and Matthews study of asparagus production is an excellent source of information on the procedures for estimating perennial crop production functions. To predict yields, the authors rely heavily on the acreage of plant age cohorts as independent variables. Unfortunately, plant age data were only available at the macro (county) level, while pollination data were only available at the micro (firm) level in cross-section data. Thus, to estimate the marginal productivity of bees, 1974 cross-section data on 117 almond growers were used. These data were provided by Pope of the University of California-Davis.

[2] It is felt that the convex *PPF* was obtained because most of the beekeepers in the sample (37 out of 48) did not produce all three outputs. In regard to the revenue function, analysis of variance on county data showed that average revenue per colony did not differ among Northern, Central, and Southern California beekeepers.

Consider then a cross-section production function for almonds, $Y = f(X_1 \ldots X_6)$, where Y is the total output of almonds in hundredweights, X_1 is total pruning expenditure in dollars, X_2 is total acreage, X_3 is total pollination in colonies, X_4 is total cultivation in dollars, X_5 is total fertilization expenditure in dollars, and X_6 is total pest control expenditure in dollars. Note that information on tree age was not available. Instead, pruning expenditure is used as a proxy variable for age because almond trees require progressively more pruning as age increases. Information on water expenditure was available. However, this information was not used because water charges and rainfall levels fluctuate widely throughout the state, thus the quantity of water used by a producer was unknown.

The following Cobb-Douglas production function was estimated using X_1 through X_6 as defined above,

$$Y = \beta_0 \left(\prod_{i=1}^{6} X_i^{\beta_i} \right) e^u,$$

where $u \sim N(0,\sigma^2)$. Table 2 shows the estimation results for three different Cobb-Douglas function models. Although there exists no truly sound method for deleting variables from regression models (Debertin and Freund), model 1 is suspect because of the abnormally high coefficient on pesticides (X_6). Likewise, model 2 is suspect because of the abnormally high coefficient on fertilizer (X_5). Because both X_5 and X_6 are highly correlated with acreage (X_2), perhaps such variables should be deleted because they are picking up the effect of acreage on production, as well as their own positive effects. Assuming one can justify such variable removal, model 3 appears reasonable in that X_2 finally has assumed its rightful importance.

In comparing these three models, we see that the coefficient on pollination varies from 0.0864 to 0.2602. Because it is difficult to say which of these estimates is more accurate, both values will be used.

Almond Production under Externality

The externality impact of pesticides on the almond industry now can be calculated in terms of the value of profit forgone due to bee deaths,

$$L = \sum_{i=1}^{N} \left[P \int_{X_{i3}0}^{X_{i3}1} (\partial Y_i / \partial X_{i3}) \cdot dX_{i3} \right]$$

where P is the price of almonds per hun-

Table 2. OLS Estimation of a Cobb-Douglas Almond Growers' Production Function

Model 1: $R^2 = 0.9056$ $SSR = 15.1577$ $n = 117$

$$\begin{aligned}\ln(Y) = &-0.1762 - 0.0235 \ln(X_1) + 0.1894 \ln(X_2) + 0.0864 \ln(X_3)\\ &(0.4661) \quad (0.0303) \qquad (0.1380) \qquad (0.0382)\\ &-0.2265 \ln(X_4) + 0.1992 \ln(X_5) + 0.7552 \ln(X_6)\\ &(0.0977) \qquad (0.1221) \qquad (0.1596)\end{aligned}$$

Model 2: $R^2 = 0.8864$ $SSR = 18.2433$ $n = 117$

$$\begin{aligned}\ln(Y) = &\ 0.9001 + 0.0382 \ln(X_1) + 0.1639 \ln(X_2) + 0.2100 \ln(X_3)\\ &(0.4443) \quad (0.0299) \qquad (0.1506) \qquad (0.0305)\\ &+ 0.0178 \ln(X_4) + 0.5390 \ln(X_5)\\ &(0.0906) \qquad (0.1067)\end{aligned}$$

Model 3: $R^2 = 0.8603$ $SSR = 22.4383$ $n = 117$

$$\begin{aligned}\ln(Y)\ &2.4938 + 0.0843 \ln(X_1) + 0.6892 \ln(X_2) + 0.2602 \ln(X_3)\\ &(0.3456) \quad (0.0314) \qquad (0.1203) \qquad (0.0318)\\ &-0.0130 \ln(X_4)\\ &(0.0998)\end{aligned}$$

Matrix of Simple Correlation Coefficients

	Y	X_1	X_2	X_3	X_4	X_5	X_6
Y	1.000	0.6004	0.8544	0.7605	0.7844	0.9106	0.9413
X_1		1.0000	0.4833	0.5294	0.4363	0.5793	0.6456
X_2			1.0000	0.5495	0.9351	0.9364	0.9089
X_3				1.0000	0.4840	0.6407	0.7470
X_4					1.0000	0.8626	0.8766
X_5						1.0000	0.9495
X_6							1.0000

Note: The figures in parentheses are standard errors.

dredweight (cwt), Y_i is the yield (in cwts.) realized by grower i, X_{i3}^0 is the number of colonies initially employed by grower i, X_{i3}^1 is the number after externality, and N is the total number of growers in the California almond industry. For ease of estimation, L was simplified to

$$\hat{L} = P\,[\text{mean }(\partial Y_i/\partial X_{i3})]\,\Delta X_3,$$

where P is the price of almonds per cwt. = \$40,00, mean $(\partial Y_i/\partial X_{i3})$ = 0.89 cwts. for model 1 and 2.69 cwts. for model 3, and ΔX_3 is a statewide estimate of the number of colonies killed while pollinating almonds equals 3,300. Performing the indicated multiplication it can be seen that $\hat{L}$ lies between \$117,480 and \$355,080.

The Burden of the Externality

As shown above, it was calculated that beekeepers lost approximately \$965,960 from pesticide damage while almond growers lost between \$117,480 and \$355,080. An interpretation of the actual meaning of these figures is important but difficult. First, consider beekeepers. Judging from their recent profitability (Reed and Horel [1976] estimate a 1975 return on total assets equal to negative 1.16%) it is at least likely that bee damage does not improve profitability.

Beekeepers can, and do, receive compensation for bee damage through the U.S. Department of Agriculture's Beekeeper Indemnity Payment Program. So long as the beekeeper can prove he was not at fault and so long as the correct government forms have been completed—the compensation will be paid at about 75% of the value lost. Beekeeper participation in the program is low because documentation of claims is difficult (Morse). For 1975 California beekeepers received \$362,285 in compensation which should be subtracted from the above loss estimate. Reimbursement occurs only once a year in April and pertains to the previous year's claims. Johnson (p. 47) points out that the indemnity program lessens incentives for beekeepers and growers to protect bees.

In contrast, the almond industry has exhibited healthy profitability. Reed and Horel (1975) calculate that the 1973 return on total assets was 18.81%. Even so, the externality is undoubtedly a costly problem to those almond growers who experience a large bee kill. It also should be noted that because almonds are an excellent source of pollen, California beekeepers and out of state beekeepers compete for almond pollination sites. Hence, losses of bees probably have not increased the price almond growers must pay for pollination.

Costs and Benefits of Bee Protection

In his 1971 survey article entitled "Honeybees, Pesticides, and the Law" Happ (p. 129) found that, "every case decided so far by the courts concerning the poisoning of honeybees has relied on the basic concept that no liability would exist if the honeybees died as a result of contact with the poison when they were operating beyond the confines of their owner's apiary." Two reasons explain why pesticide users traditionally have been assigned property rights to the land upon which bees forage without paying rent. First, while it is easy to determine if pesticides were the cause of bee deaths, it is difficult to determine the location of such pesticide contamination. Unless evidence actually shows that the apiary itself was sprayed, it is assumed that the foraging bees contacted pesticides away from the apiary and transported the contamination back to the hive. Note that in pollination contracts beekeepers receive protective guarantees regarding the grower's use of pesticides. Thus when damage occurs during pollination, it usually is caused by bees traveling to neighboring fields.

The second reason pesticide users hold the property right is that the products of beekeepers and growers who rely on bees account for only 5% of California's agricultural revenue. Here political power (as indicated by such revenue) plays a key role. The political decision as to which party is liable for damages seems to have been made in an analogous manner to that described by Samuels in his article on cedar rust and apple trees.

The Case of Tulare County Citrus

While most citrus varieties do not require bees for pollination, bees do obtain substantial nectar yields from citrus blossoms. Therefore, many beekeepers annually transport their bees to citrus regions in order to take advantage of this honey flow. A beekeeper will sometimes give the grower a payment in honey in order to

locate on that grower's property. More often, however, the beekeeper will locate on adjacent property to avoid paying an apiary rent. The bees still realize a substantial nectar yield simply by trespassing.

During the 1974 citrus bloom, citrus cutworm infested the Tulare County groves, thereby forcing growers to spray. The result was a substantial bee kill and drastically reduced honey yields. A survey by the Tulare County Agricultural Commissioner indicated that every colony in the county was adversely affected to some degree.[3] Without waiting another season to see if beekeepers and growers could solve this problem by themselves, in 1975 the commissioner began a rigorous program of forcing pesticide applicators to alter their treatment programs so as to protect bees.

In order to both adhere to the commissioner's regulations and to control the cutworm, most growers switched from daytime applications of Sevin and Guthion to night and early morning applications of Lannate. Such a practice has not adversely affected yields, but it has raised costs an average of $8 per treated acre. Because (*a*) Tulare citrus land has averaged 91,100 acres for the period 1974–78 and (*b*) since 1974, approximately 35% of this acreage has been worm-infested, the citrus industry's bee protection costs have averaged $255,080 per year. In regard to beekeepers, the costs which citrus pesticide damage imposed for the period 1974–78 are shown in table 3.

One can now estimate the net change in incomes arising from the adoption of a liability law which protects bees. First calculate the average amount beekeepers save each year from protection. This can be done by taking the difference between their 1974 loss (when bees were unprotected) and the yearly average of their 1975–78 losses (when bees were protected)

1974 beekeepers' losses	= $1,324,650
Average 1975–78 beekeepers' loss	= $ 346,760
Average annual amount beekeepers' saved	= $ 977,890

Then, taking the difference between the average amount beekeepers save and the average amount growers spend obtains an estimate of the net gain from pesticide regulation enforcement

Average annual amount beekeepers' save	= $ $977,890
Average annual amount growers spend	= $ 255,080
Average annual net gain	= $ 722,810.

Hence, the Tulare County regulations do generate a positive net gain.[4]

Suppose policy makers decide to reassign property rights in favor of the citrus grower. This could be accomplished through a program whereby beekeepers pay a tax to the commissioner in order to locate their bees in Tulare during citrus bloom. The intent of the

[3] The indirect effect of this loss on almond pollination is not thought to be significant because so many beekeepers compete for almond pollination sites.

[4] The number of beekeepers who received government indemnification for this damage is not known. However, indemnification is thought to be paid in about one out of every four cases of damage (Morse). Note that (*a*) because indemnification reduces the beekeeper's loss, it consequently reduces the beekeeper's gain from Tulare bee protection. Also, (*b*) because such indemnification is paid with public funds, the Tulare program may increase the welfare of unrelated U.S. taxpayers since less indemnification is required.

Table 3. Bee Colony Damage and Cost Estimates, Tulare County

		Colony Damage and Cost						
		Killed		Severe		Moderate		
Year	Total Number of Colonies	Number	Cost	Number	Cost	Number	Cost	Total Cost of Damage
			$		$		-----	$ -----
1974	150,000	0	0	7,500	155,775	112,500	1,168,875	1,324,650
1975	150,000	0	0	1,500	31,155	67,500	701,325	732,480
1976	150,000	0	0	700	14,539	12,000	124,680	139,219
1977	275,000	0	0	0	0	48,400	502,876	502,876
1978	121,085	0	0	0	0	1,200	12,468	12,468

Source: Tulare County Agricultural Commissioner; costs are based on the estimates in equation (2), and each killed colony is valued at $31.16. Using an established industry rule of thumb, severely and moderately damaged colonies are valued at two-thirds and one-third this amount, respectively.

tax would be to compensate growers who have adopted special pest treatment techniques solely to protect bees. The program could use the same personnel who presently enforce the bee protection area. If the bee population was 169,217 colonies (the average 1974–78 level) and the tax was intended to raise the extra $255,080 growers spend, it would equal $1.51 per colony.

This plan would accomplish two important results. First, it would bring a profitable cooperation between beekeepers and growers because growers would benefit financially (or at least not lose) from the presence of bees. Such cooperation could let bees locate in the growers' fields and also let beekeepers place their hives at higher densities. Second, it would defuse a lot of hostility between beekeepers and growers. Those who subscribe to the Coasian point of view may feel that the best solution in terms of total income would be to abolish all bee protection measures. While this may be true in the long run, today such a change cannot receive serious consideration in light of the successful performance of the existing protection arrangement.

Conclusion

It has been shown that beekeepers suffer substantial financial losses when their bees are damaged by pesticides. For 1975, losses equaled $965,960, or more than 4% of California beekeepers' annual income. In contrast, almond growers, who must depend on bees for pollination, suffer much less from beekills, with losses equaling at most 0.3% of total income. Such a different relative impact results because many colonies are damaged, but few are damaged while pollinating almonds. Furthermore, the pollination rents almond growers pay are kept low because both California and out-of-state beekeepers compete for almond sites.

In examining the case of Tulare County citrus, it has been shown that substantial net financial benefits ($722,810 annually) arise from mandatory requirements to protect bees. However, should policy makers feel it is unfair to so restrict growers without providing compensation, an alternative plan has been outlined. This would involve taxing all bee colonies located in Tulare County during citrus bloom. The proceeds of the tax would compensate growers who, in turn, would still be required to protect bees.

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References

Castle, Emery N. "The Market Mechanism, Externalities, and Land Economics." *J. Farm Econ.* 47(1965):542–56.

Cheung, Steven N. S. "The Fable of the Bees: An Economic Investigation." *J. Law Econ.* 16(1973):11–33.

Debertin, David W., and R. J. Freund. "The Deletion of Variables from Regression Models Based on Tests of Significance: A Statistical and Moral Issue." *S. J. Agr. Econ.* 7(1975):211–15.

French, Ben C., and Jim L. Matthews. "A Supply Response Model for Perennial Crops." *Amer. J. Agr. Econ.* 53(1971):478–90.

Happ, Gregory W. "Honeybees, Pesticides, and the Law." *Gleanings in Bee Culture.* 99(1971):128–9.

Hasenkamp, Georg. *Specification and Estimation of Multiple Output Production Functions.* Berlin: Springer-Verlag, 1976.

Henderson, James M., and Richard E. Quandt. *Microeconomic Theory*, 2nd ed. New York: McGraw-Hill Book Co., 1976.

Johnson, David B. "Meade, Bees, and Externalities." *J. Law Econ.* 16(1973):35–52.

Klein, Lawrence R. *A Textbook of Econometrics.* Evanston, Ill.:Row, Peterson, 1953.

Mann, Jitendar S. "Techniques to Measure Social Benefits and Costs in Agriculture: A Survey." *Agr. Econ. Res.* 29(1977):115–26.

Meade, J. E. "External Economies and Diseconomies In a Competitive Situation." *Econ. J.* 62(1952):54–67.

Morse, Roger A. "Pesticides—Where Are We Going?" *Gleanings in Bee Culture* 105(1977):245–46.

Pope, Rulon D., Jr. "An Analysis of Factors Affecting Farm Diversification with Special Attention to San Joaquin Valley Crop Farms." Ph.D. thesis, University of California, Berkeley, 1976.

Reed, A. D., and L. A. Horel. *Almond Production Costs in California.* University of California Leaflet No. 2231, Nov. 1975.

———. *Bee Industry Economic Analysis for California.* University of California Leaflet No. 2345, April 1976.

Samuels, Warren J. "Interrelations between Legal and Economic Processes." *J. Law Econ.* 14(1971):435–50.

Sheesley, Bob, and Bernard Poduska. "Strong Honeybee Colonies Prove Value in Almond Pollination." *California Agriculture* 24(1970):4–6.

Siebert, John W. "Almonds, Bees, and Externalities in the California Agricultural Economy." Ph.D. thesis, University of California—Berkeley, 1978.

Tulare County Agricultural Commissioner. 16 December 1977 Bee Meeting Notes. Visalia, California, 1977.

Optimal Stochastic Control of U.S. Wheat Stocks and Exports

Oscar R. Burt, Won W. Koo, and Norman J. Dudley

A stochastic dynamic programming model was developed to estimate optimal strategies for U.S. wheat reserves policy using the results of an econometric model which reflects the complex dynamics of supply response. Empirical results indicated that U.S. producers are the beneficiaries of a wheat storage program, while domestic and foreign consumers are relatively small and large losers, respectively. Another result is that wheat storage capacity in excess of 2 billion bushels is difficult to justify economically.

Key words: buffer stocks, commodity storage, dynamic programming, grain reserves, price stabilization, wheat.

The tendency noted by Thurow for economists to concentrate their research efforts on popular problems and issues of the times is exemplified by the recent flood of research in agricultural economics—both theoretical and empirical—on commodity storage questions. The theoretical research has focused on generalizations of the questions raised in the early work of Waugh, Oi, and Massell; the major contribution in methodological approach was made by Turnovsky (1976). The empirical work has used simulation, e.g., Reutlinger; Sharples, Walker, Slaughter; and Zwart and Meilke; and several control theory or dynamic programming applications have been made (Arzac, Taylor and Talpaz, Gustafson, Johnson and Sumner, and Cochrane and Danin).

Much of the recent theoretical work places heavy demands on empirical measurement of supply and demand relationships (see Just and Hallam for a brief survey). Although consistently confirming that price stabilization improves global welfare, the theoretical results indicate that the distribution of benefits from storage between producers and consumers is related critically to the curvature of the demand and supply functions, as well as to the way in which stochastic disturbances act on the relationships, additive versus multiplicative (Turnovsky 1976). We must also recognize that the distribution of benefits is dependent on institutional arrangements in the international trade arena (Just et al.). The available data for distinguishing between various functional forms or stochastic specifications on the disturbances are limited. The recent empirical research of Just and Hallam reinforces our opinion that the statistical significance needed for the necessary discernment is weak.

Most of the theoretical work considers only the two polar cases of no storage versus sufficient storage to stabilize price completely (Turnovsky 1974, 1976, and Just et al.). Storage costs are assumed to be zero and discounting is not used. Quite apart from the loss of production and consumption adjustments in response to price signals, complete stabilization of prices will not be economically optimal with either discounting or positive storage costs. The trade-off created by storage costs is rather obvious, but some price variation should exist under discounting, even with zero storage costs, because the buffer stock required to stabilize prices completely has an opportunity cost.

In a dynamic optimization model, where short-run information on production and consumption is incorporated into the stochastic sequential decision framework, it would seem that benefits are more likely to accrue to both consumers and producers than has been found to be the case for the simplified theoretical

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models. An optimization model which uses the expected sum of producers' and consumers' surpluses as a criterion does give weight to each group, while a simple comparison between no storage and sufficient storage to remove all price variability (using the same criterion) easily could be a comparison of two relatively bad extremes, neither worth serious consideration.

Although the foregoing casts doubt on the relevance of the theoretical results for empirical commodity storage models, it is only prudent to perform sensitivity analysis in our empirical studies. If the capability of econometric methodology and our weak data base is inadequate to discern the curvature of demand and supply functions, or to discern between additive versus multiplicative disturbance terms, our only recourse is to use a good deal of sensitivity analysis and hope that negative results are not forthcoming.

This study of the U.S. wheat industry was an attempt to develop the methodology for a stochastic dynamic optimization model which would fully exploit short-run information on supply response and demand for U.S. wheat exports. A detailed econometric study was undertaken to estimate wheat supply response, and a Box-Jenkins type time-series analysis was done on annual export prices at the Gulf ports to provide short-run information on export demand. The optimization model is that of Markov process dynamic programming (Howard) with an adaptation to exploit extra information beyond that contained in the formal state variables.

The Econometric Model

Wheat supply response was factored into acreage and yield equations, which makes quantity produced the product of these two equations. Demand was divided into four components: (*a*) domestic food, (*b*) domestic livestock feed, (*c*) seed, and (*d*) exports.

Wheat Acreage Equation

Because of complexities in government programs before 1961, the sample of time-series data used was for the crop years 1960/61 to 1975/76; the last year of the crop-year is the year wheat was harvested. Government policy variables were patterned after the research of Garst and Miller, except that acreages going into the diversion and set-aside programs were thought by the authors to be jointly dependent with acreage seeded to wheat. These acreage variables were replaced by dummy variables to indicate the years in which the programs were operative, but the set-aside dummy did not show statistical significance.

After adjustment of policy variables to no government programs, the wheat acreage equation was

$$
\begin{aligned}
(1)\quad A_t = {} & -20{,}881 + \underset{(20.2)}{12{,}232\,FGP_t} + \underset{(22.5)}{6553SP_{t-1}} \\
& + \underset{(5.3)}{1886P_{t-1}} + \underset{(67.8)}{15{,}138P_{t-2}} + \underset{(15.9)}{.3733A_{t-1}} \\
& - \underset{(17.1)}{.4288A_{t-2}} + \underset{(21.1)}{.4857A_{t-3}} + u_t,
\end{aligned}
$$

$$
(2)\qquad u_t = \underset{(16.9)}{-.921u_{t-1}} + \epsilon_t,
$$

$$
\bar{R}^2 = .9999 \text{ and } s = 74,^{1}
$$

where FGP is the feed grain price index; A is acres seeded in thousands; SP is September price the fall before harvest; P is crop-year (1 July to 30 June) average price, and u is the stochastic disturbance term. Approximate t-ratios (absolute values) are in parentheses below the respective parameter estimates. Prices include government subsidies on a per bushel basis and are deflated by the index of prices paid by farmers for production items. (All deflators of the study are 1967 base.) September price is average market price received by farmers plus the average subsidy per bushel during the crop year in which September falls. Short- and long-run elasticities at sample means are 0.22 and 1.44, respectively.

The weakest aspect of the acreage equation was only two degrees of freedom, but it sequentially predicted one year ahead beyond the sample with much better precision than the best alternative model. Because the decision was made to use (1) in the storage model, two more years of data have become available and the one year ahead predictions have been within 4% error of the mean of 60 million acres, but there is some evidence of underestimation because prices have abruptly declined.

Individual coefficients on lagged prices and acreages in (1) cannot be interpreted directly, but must be taken jointly as a rational lag approximation to the underlying lag distribu-

[1] $\bar{R}^2$ is the adjusted coefficient of determination which includes the explanatory value of serial correlation, and s is the standard error of the estimate.

tion on wheat prices (Griliches). The lag distribution has a somewhat irregular pattern which probably is caused by the heavy influence of summer-fallow in the Great Plains, also suspected as the source of negative serial correlation in the disturbance term.

Wheat Yield Equation

A new methodology using a nonstochastic difference equation was applied to estimate aggregate U.S. wheat yield response. Independent variables are trend, t, season average wheat price, P_t, and planted acreage, A_t, and the dependent variable is bushels per acre, Y_t. The equation used in this study was estimated for the sample period of crop years 1953/54 to 1975/76:

$$
\begin{aligned}
(3)\quad Y_t = & -31.87 + \underset{(6.8)}{.350t} + \underset{(4.8)}{5.66P_{t-1}} \\
& + \underset{(6.7)}{4.67P_{t-3}} + \underset{(2.1)}{1.82P_{t-5}} - \underset{(6.7)}{.000182A_t} \\
& + \underset{(8.9)}{.791E(Y_{t-1})} + u_t, \text{ and}
\end{aligned}
$$

$$
(4)\quad u_t = -\underset{(5.4)}{1.06u_{t-1}} - \underset{(2.2)}{.44u_{t-2}} + \epsilon_t.
$$

$$\bar{R}^2 = .900 \text{ and } s = 1.10$$

The expression $E(Y_{t-1})$ is the unconditional expectation of Y_{t-1}, which implies a first-order, nonstochastic, difference equation in the mean of the dependent variable (Burt). The unconditional expectation implies that $E(Y_{t-1})$ does not take account of the information available from the serially correlated disturbance term as given in (4). Prices are deflated the same as in the acreage equation.

The estimation procedure can be interpreted as maximum likelihood estimation of a rational lag specification with the denominator of the rational function being the same for all independent variables (Burt). The parameter estimators of P_{t-2} and P_{t-4} were highly correlated (negatively) with adjacent lagged prices, which destroyed any individual significance on the prices; therefore, these two prices were omitted. The implied lag distribution is smooth in spite of the omitted price variables. The negative serial correlation most likely stems from crop rotation constraints, particularly with summer-fallow in the Great Plains.

Domestic Wheat Demand Equations

Because United States export decisions appear to be made independently of those for domestic consumption and are dominated by exogenous world events, we assumed that price is largely exogenous for purposes of estimating domestic demand.

Per capita demand for food (bushels) was estimated for the period of crop years 1950/51 to 1974/75:

$$
\begin{aligned}
(5)\quad C_t = & 1.264 + \underset{(2.0)}{6.735/(t + 10)} \\
& - \underset{(2.4)}{.0284P_t} + \underset{(1.8)}{.440E(C_{t-1})}.
\end{aligned}
$$

$$\bar{R}^2 = .990 \text{ and } s = .022$$

The reciprocal trend was introduced to reflect the increasing margin over time between the consumer and farm level prices, and the number 10 in the denominator was obtained by a search on the error sum of squares. The first-order difference equation reflects habit formation in consumer behavior and implies a geometric lag distribution on price. Various models which were tried suggested that the net effects of the trend and $E(C_{t-1})$ terms were seriously confounded. Correlation between these two parameter estimators is $-.9986$ in (5), which explains the low t-ratios on these two parameter estimates. The price variable was adjusted for the 75¢ per bushel marketing certificates during 1964–73 and deflated by the food price index. Per capita income was insignificant when introduced into (5).

Total domestic demand for livestock feed was estimated for the crop years 1956/57 to 1975/76, giving

$$
\begin{aligned}
(6)\quad QF_t = & -460{,}200 - \underset{(2.2)}{112{,}400P_t} \\
& + \underset{(1.2)}{74{,}240FGP_t} + \underset{(1.8)}{8.857GCAU_t},
\end{aligned}
$$

$$\bar{R}^2 = .636 \text{ and } s = 43.410$$

where QF is thousand bushels of wheat fed to livestock; P and FGP, as well as the deflator, are the same as in the acreage equation; while $GCAU$ is grain consuming animal units (thousands).

Wheat seed demand was estimated as a linear function of seeded acres,

$$
(7)\quad QS_t = -2702 + \underset{(44.6)}{1.195A_t},
$$

$$\bar{R}^2 = .991 \text{ and } s = 810$$

where QS is thousand bushels of wheat demanded for seed, and A is thousand acres seeded. The sample period was 1956/57 to 1975/76.

Autoregressive Export Price Equation

Rather than try to estimate an econometric model to explain demand for U.S. wheat exports, a Box-Jenkins type time-series analysis was made on market price at the Gulf of Mexico ports. Variables such a world stocks of grain are reflected indirectly in the systematic structure of the time-series model, i.e., lagged prices and moving average error terms. An advantage of this approach for the wheat storage model is parsimony in the number of state variables needed, and also, simplifications in the stochastic transition equations to describe movement of the state variables over time.

The time-series model of price changes can be interpreted as representative for average U.S. exports over the time-series sample used in the estimation. Then, an independent estimate of demand elasticity for U.S. wheat exports, where quantity is measured from the time-series mean, is introduced into the time-series equation for export price.

The final equation from the time-series analysis over the sample period 1959–75 was

$$(8)\quad ln(WP_t) = .1604 + \underset{(6.3)}{.7127}ln(WP_{t-1}).$$
$$\bar{R}^2 = .827 \text{ and } s = .117$$

The Gulf price, which we denote by *WP* to symbolize "world price," is deflated by the U.S. consumer price index. A second-order autoregressive equation was only marginally significant over the first-order equation in (8), and would imply another state variable in the storage model. A moving average error jointly with the first order autoregressive specification was tried, but with little improvement. A dummy variable was introduced for 1973, because that year consistently gave an unusually large residual, suggesting an outlier.

The price elasticity of demand for U.S. wheat exports was estimated by aggregating world regional demand elasticities estimated by Konandreas; average quantities exported to individual regions were used as weights. This elasticity of −2.5 was close to the −3.0 estimated directly by Konandreas and Schmitz.

Let η be the estimated price elasticity, while $\bar{p}$ and $\bar{x}$ denote mean price and exports, respectively. Then a term to reflect the influence of U.S. exports on price is given by

$$(9)\qquad dp/dx \simeq \bar{p}/\bar{x}\eta.$$

Price at the Gulf, our proxy for world price, was specified to obey the following relationship derived from (8) and (9),[2]

$$(10)\quad WP_t = 1.222(WP_{t-1})^{.7127} + .95(10)^{-6}(x_t - \bar{x}),$$

with exports measured in 1,000 bushels. Mean price and exports were \$1.81 and 765 million bushels, respectively.

Equation (10) is viewed as the demand for U.S. wheat exports. Note, however, that the price variable is price at the Gulf, while prices in the other equations are average prices received by farmers. A single price variable was obtained by using the Gulf price as a "standard" and regressing average price received by farmers (excluding subsidies) on the Gulf price.

The Stochastic Storage Model

Computational solutions are obtained by approximating the continuous state variables by many discrete intervals which results in a Markovian sequential decision process with a finite number of states. The only decision variable is quantity of wheat exported that indirectly controls year-to-year carryover. Otherwise, free market conditions are assumed in the wheat industry with no government controls on production.

Because the disturbance term in the export price equation (10) is assumed unknown at the time a storage policy decision is made, a specific level of exports does not determine price but only the probability distribution. The probability distributions for price and the disturbances in supply and demand in conjunction with the state variables then determine the distribution of domestic consumption, production, and ending carryover for the ensuing crop year. If exports had been estimated as a function of world price with the random disturbance reflecting variations in exports for a given price, then price (or at least a "target" price) would have been a logical choice of decision variable (Taylor and Talpaz). Some studies, e.g., Cochrane and Danin, have assumed that random disturbances are known at the time decisions are made; this makes the

[2] One problem with this approach in a dynamic optimization model is that exports can be controlled over time to manipulate this lagged price which we would like to assume is exogenous. The sensitivity analysis on misspecifications in the model which are reported later suggest that this could be somewhat of a problem.

choice of a decision variable much more flexible, in fact, arbitrary.

Stage length, or interval between decisions, is one year. It should begin when most information is available for decision making—we chose 1 September. Stocks then become last year's carryover plus production from the harvest just completed. The primary price used as a state variable is average price at the Gulf during the preceding crop year which ended 30 June.

In a straightforward application of dynamic programming to the wheat storage model, there is a total of fifteen state variables. For example, the acreage equation in (1) requires that September price, first- and second-order lagged seasonal prices, and first- through third-order lagged acreages be entered as state variables, making a total of six. Another state variable would be needed to incorporate information stemming from serial correlation in the disturbance term. In general, a lagged price or quantity variable in a component equation of demand or supply requires representation via an extra state variable in the dynamic optimization model. Also, a serially correlated disturbance term in a component equation of demand and supply implies state variables equal in number to the order of serial correlation. The implicit variables $E(Y_{t-1})$ and $E(C_{t-1})$ in (3) and (5), respectively, are treated as lagged variables in this respect and each requires a state variable in the decision model.

A Proximate Solution Method

As it is not feasible to work with a model containing fifteen state variables, some approximation had to be developed. The method used is a variant of that suggested by Arrow.

The general recursive equation of dynamic programming is

$$(11) \quad v_n(\mathbf{y}) = \underset{x}{\text{Max}} \Big(g_n(\mathbf{x},\mathbf{y}) + \alpha E\{v_{n-1}[T_n(\mathbf{x},\mathbf{y})]\}\Big),$$

where $\mathbf{y}$ and $\mathbf{x}$ are vectors of state and decision variables, respectively, and $E[\cdot]$ is the expectation operator. In the wheat storage problem $v_n(\mathbf{y})$ is the present value of expected net benefits over an n-year planning period when following an optimal storage policy and given that the initial state vector is $\mathbf{y}$; α is the discount factor with $0 < \alpha < 1$. The function $g_n(\mathbf{x},\mathbf{y})$ is expected annual net benefits from the first year of n future years, while $T_n(\mathbf{x},\mathbf{y})$ is the transformed vector of state variables at the beginning of a planning horizon of $n - 1$ years. Actually $T_n(\mathbf{x},\mathbf{y})$ is a random variable and the function notation is used to show that $\mathbf{x}$ and $\mathbf{y}$ enter as parameters in the multivariate distribution function of the vector of state variables. The subscript n on $T_n(\mathbf{x},\mathbf{y})$ implies that the probability distribution is permitted to change from stage to stage in the decision process.

The approximation discussed by Arrow is to replace $v_{n-1}(\cdot)$ in (11) by an estimate of some kind. The usual computational method of dynamic programming calculates the function $v_n(\cdot)$ recursively starting with $v_0(\cdot)$ as a given function. But now we are considering some a priori estimate of $v_{n-1}(\cdot)$ in order to estimate the optimal decision rule for stage n only. It is seen from (11) that if $v_{n-1}(\cdot)$ were a known function, the optimal decision for stage n could be obtained from a static optimization algorithm.

The approximation suppresses all state variables except two judged to carry the most information in the decision process when considering all components of the demand and supply equations jointly with the world wheat price equation. Obviously, stocks of wheat are a crucial state variable, and the second variable chosen was wheat price lagged one year (Gulf price being used as a standard instead of average price received by farmers). Details of how the model in (11) can be modified to suppress certain state variables are discussed later.

The following dynamic programming recurrence relation, containing two state variables and one decision variable, is introduced to explain the method

$$(12) \quad f_n(s,p) = \underset{x}{\text{Max}} \Big[G_n(x,s,p) + \alpha E\Big(f_{n-1}\{s - x + w_n(x,p), [1.22p^{.713} + .95(10)^{-6}(x - \bar{x})]u\}\Big)\Big],$$

where x, s, and p are wheat exports, stocks, and season average price last crop year, respectively; $G_n(x,s,p)$ is expected annual net benefits in stage n, and $w_n(x,p)$ is a random variable representing net production after subtracting domestic consumption. The transformation equation for the price state variable is (10) with a multiplicative random error, u, which does not depend on the decision or state variables.

Step one. The first step truncates trends in the component equations of demand and supply so that the decision process is stationary over

time. Therefore, the subscript n is redundant on $G_n(x,s,p)$ and $w_n(x,p)$ for this first step of the procedure. An arbitrary value such as zero is assigned to $f_0(s,p)$ and the usual recursive computational method (see Bellman) is used to solve (12) for a reasonably long planning horizon which we denote by k. The application used k equal to 20, corresponding to years 1981–2000.

The most important output from this first-step solution is the expected value function, $f_k(s,p)$; with it we are ready to begin the second step of the approximation procedure and start bringing in additional information associated with the other state variables.

The relationship between chronological time, stages of the decision process, and dates used in the application is given in figure 1. The time at which an actual decision is to be made is t equal to zero, which corresponds to stage number $k + 5$ and year 1976. The highest order lagged variable in the component equations of supply and demand is the fifth-order lagged price in the yield equation in (3); this highest lag determined the configuration chosen in figure 1. At stage $k + 1$, which corresponds to t equal to 4, the fifth-order lagged price is a known datum, but would be unknown for t greater than 4. Therefore, only the two state variables of the model are known information when $t \geq 5$, i.e., $n \leq k$.

Remaining steps. In the second step, we set n equal to $k + 1$ in (12), which lets us substitute the known function $f_k(s,p)$ for $f_{n-1}(s,p)$ in (12). The expected immediate net benefit function, $G_{k+1}(x, s, p)$, is calculated with price lagged five years (measured from the beginning of the year associated with stage $k + 1$) taken as a given datum. Likewise, the fifth-order lagged price is taken at its actual level in the definition of the random variable $w_{k+1}(x,p)$. Recognition of this known fifth-order lagged price at stage $k + 1$ gives an improvement in the calculation of $f_{k+1}(s,p)$ which would not be possible by merely iterating the general two-state-variable model of the first step in the approximation one more time.

At stage $k + 2$, not only the fifth-order but also the fourth-order lagged price is known information. However, the latter does not enter any of the components of demand or supply. Therefore, the third step of the approximation is simply a repeat of the second step; but, of course, the fifth-order lagged price is measured from the year associated with stage $k + 2$ and is a different value (usually) than used in the second step. This provides us with $f_{k+2}(s,p)$.

At stage $k + 3$, third- through fifth-order lagged prices are known data as well as third-order lagged acreage, which appears in the acreage response equation in (1). The fourth step in the approximation takes these lagged variables as known data with respect to the probability distribution of $w_{k+3}(x,p)$ and the expectation operation to obtain $G_n(x,s,p)$, and another iteration of (12) is made to obtain $f_{k+3}(s,p)$.

The fifth step of the approximation puts us at stage $k + 4$, where lagged prices and acreages of orders higher than the first are known data. Probability distributions associated with (12) are defined with these lagged variables as given data, and another iteration yields $f_{k+4}(s,p)$. Second-order serial correlation in the disturbance of the yield equation in (3) could have been incorporated into the probability distributions too, but we did not do so in the application.

The last step of the approximation brings us to stage $k + 5$, the beginning of the actual planning horizon for which a decision is wanted, and all lagged variables including first order are known data. Also, the information contained in the serial correlation of the disturbances in (1) and (3) can be used by the standard forecast methods. We take all of this information into account in the definition of probability distributions to make the final iteration on (12), thus obtaining $f_{k+5}(s,p)$ and the final decision rule from the maximization operation in (12).

A review of the method reveals successive improvement in the approximation of $v_{n-1}(\cdot)$ in (11). Each iteration, beginning with stage k + 1, brings in known data at that stage for all of the state variables, not just s and p. At the final stage $k + 5$, all the state variables are known data and have an opportunity to exert their

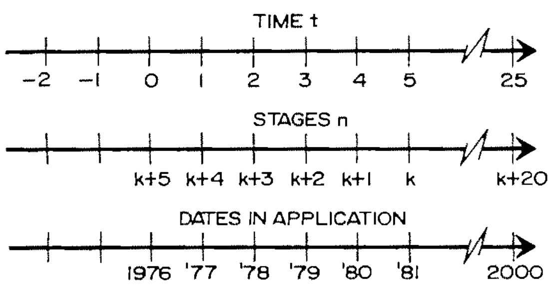

Figure 1. Relationship between stages and chronological time

influence on the final decision. Therefore, at the final stage of calculations where the decision rule is going to be actually applied, we have a relatively good approximation for $v_{n-1}(\cdot)$, and the final optimization is viewed as an application of Arrow's proximate method to the original problem containing the full set of state variables.

Let it be clear that this entire computational process should be repeated each year, including an annual update of econometric relationships, so that decisions are based on the most recent information available.

State variable suppression. Now return to the problem of suppressing state variables, a necessary task for carrying out the proximate solution method. In principle, state variables in a stochastic model can be suppressed by using an unconditional joint distribution instead of a conditional distribution for the transition of the remaining state variables from stage to stage. However, a difficulty arises because the probability distribution is dependent on the decision rule applied. An iterative procedure could be used where an a priori decision rule is used to get the unconditional joint distribution of the state variables not suppressed; then the optimal decision rule is derived taking this distribution as given. The next iteration would use that decision rule just calculated in place of the a priori rule, and the computations completed again. Several iterations would be expected to give a convergent decision rule which would then be taken as the optimal decision rule for the model with a reduced number of state variables.

Although the methodology described in the above paragraph was the guiding principle, a more expeditious method was used in the wheat storage problem. The existence of a market equilibrium price for the wheat industry in the United States, when the trends in yield and domestic food demand are truncated, suggested a simple procedure to suppress all of the state variables except wheat stocks and last year's price.

We illustrate the procedure with the acreage equation in (1). First, an estimate was made of long-run equilibrium price of wheat which permitted long-run acreage to be calculated from (1). This long-run acreage was then substituted into (1) in place of the three lagged acreage variables which collapses these variables into the intercept of (1). Second, each price variable in (1) was regressed on the Gulf price of crop-year $t-1$, and these three simple regressions were used to replace the prices in (1) with a single price, *viz.*, the price state variable. The final result is a linear equation in the price state variable, and all lagged variables have been removed except the state variable.

The final task is in handling the stochastic specifications of the acreage equation. As a compromise in the direction of a Bayesian approach, the standard deviation of the disturbance term was approximated by the standard error of prediction instead of the standard error of the estimate, thus taking into account the variability of the parameter estimators in the equation. However, the standard error of prediction changes with the values assigned to the independent variables, so we took the value for 1976 as an approximation throughout, in order to simplify the computations. The serially correlated disturbance was handled by using its unconditional distribution which ignores the dependence structure of (2) and inflates the variance of the disturbance term; that is to say, we used u_t instead of ϵ_t in (2) as the disturbance.

The three simple regressions between lagged average prices received by farmers and the Gulf price introduce additional disturbance terms into the simplified acreage equation. We included the disturbance terms in these regressions when making the substitutions for prices and followed through the statistical implications for increased variability in the overall disturbance term of the acreage equation. In so doing, parameter estimates were taken as given at their point estimates in the price regressions, and the standard deviations of the disturbances were estimated by the standard errors of the estimate for the respective equations.

Space does not permit giving comparable details on how the other component equations of demand and supply were simplified, but the estimated equilibrium price was exploited to reduce each equation to only one independent variable, *viz.*, the price state variable. The final result provided a model with all state variables suppressed except for wheat stocks and first-order lagged price at the Gulf. This storage model can be interpreted as an approximation which should provide good results if existing conditions, and the recent history of those conditions, are not "too far" from the equilibrium state. We rely on the successive iterations for stages $k+1, k+2, \ldots, k+5$ to

accommodate initial conditions substantially removed from the long-run equilibrium.

For the last few iterations where known information on all state variables is exploited, equations such as that for acreage were simplified in all stages except $k + 5$, but known values of lagged variables and trend were utilized in the simplifications. In general, the variances of disturbance terms in the simplified equations become smaller as the stage increases from k to $k + 5$, i.e., as we move in time from $t = 5$ to $t = 0$. At stage $k + 5$ ($t = 0$) when all lagged variables are known data, the variance of the disturbance term was taken as the square of the standard error of prediction in (1).

The required estimate of long-run equilibrium price can be obtained by solving the system of equations for the wheat industry which encompasses all components of demand and supply. The dynamic equations must be transformed into their long-run forms and trends truncated at some arbitrary level. Prices received by farmers are transformed into price at the Gulf by a linear regression between these two prices. Equilibrium price was calculated to equal \$3.22 in 1976 dollars (\$1.89 in 1967 dollars) which is reasonably close to expected value of price from the optimization model, \$3.14.

Of course, the component demand and supply equations derived by suppressing state variables are not long-run equations in the sense of the above paragraph, even the ones associated with stages 1, 2, . . . , k. These equations with suppressed state variables are annual adjustment equations, but with only the price state variable as an argument, and the intercepts have been adjusted to correspond to a recent history of long-run equilibrium prices and quantities.

Probability Distributions for Net Production

The aggregate supply function for wheat is obtained by multiplying (1) and (3) together, which gives a rather complicated structure in the random disturbance. Because the yield equation contains acreage as an independent variable, the multiplication results in a term involving the product of the disturbance terms from the separate yield and acreage equations. This complicating factor in the stochastic specification of supply led to the use of a Monte Carlo approach to estimate a cumulative distribution function (CDF) for net production, i.e., production minus all domestic consumption components. Net production is the random variables $w_n(x,p)$ in (12).

Technically, a separate CDF would need to be estimated for each discrete pair of values (x,p) used in the computational algorithm at a given stage n. The long-run model for stages 1, 2, . . . , k assumes a stationary decision process, thus requiring only one set of CDF's, but a separate set of CDF's is required for each stage $k + 1$, $k + 2$, . . . , $k + 5$.

In the empirical study, we made a further simplification by removing exports, x, as a parameter in the CDFs; only the price state variable, p, entered as a parameter. The relatively small impact that changes in exports would have on domestic consumption was considered quite trivial relative to the variability in the random error for net production.

For each stage where a separate set of CDFs was required, a separate CDF was estimated for each discrete price interval. Usually a sample of 500 was used in the Monte Carlo procedure to get sample points for the CDF, and then a polynomial was fitted to these sample points. Normally distributed disturbances were assumed in the various component equations of demand and supply.

The other random variable, u, in (12), which is associated with the price state variable, was assumed to follow the log-normal distribution and to be independent of the net production random variable, $w_n(x,p)$.

The Criterion Function

Two separate criterion functions are used in the analysis: (*a*) domestic, and (*b*) world welfare. The domestic criterion is the sum of domestic consumers' and producers' surpluses minus storage costs. The world welfare criterion contains consumers' surplus associated with the export demand equation in addition.

Computation of the annual expected net benefit function under either criterion was greatly simplified by replacing random variables by their mean values in the demand and supply equations. In the case of the component demand equations, this simplification is justified by the Simon-Theil certainty equivalence theorem for quadratic criteria functions because the demand equations are linear, making the associated value measures quadratic. However, the supply equation is quadratic in

price after multiplying yield and acreage together, which makes the certainty equivalence theorem only approximately valid (Malinvaud). Let it be clear that we are appealing to the certainty equivalence theorem in a limited sense for the overall optimization problem, *viz.*, for the single-stage maximizations in (12) and only with respect to how $G_n(x,s,p)$ is calculated. The stochastic linkage from stage to stage through the state variable transformation equations, containing the random variables $w_n(s,p)$ and u, does not rely on linear approximations through the certainty equivalence theorem.

The usual theoretical justification for using areas under demand and supply equations as measures of social value and cost is based on static demand and supply equations (Hotelling). The food demand, acreage, and yield equations for wheat are dynamic because they contain lagged values of the quantity measures and prices in their right-hand sides. These equations can be transformed into long-run equations by well-known manipulations, as contrasted to their interpretation as conditional short-run equations when presented as dynamic regression equations. It would appear that a long-run interpretation of these equations would more nearly fit received theory for static equations in regard to measuring social values and costs.

The yield equation presented special problems because yields are clearly a nonstationary process and have been subject to rapidly changing technology during the sample period used to estimate (3). It was our judgment that the term for $E(Y_{t-1})$ is confounded with trend and should not be used to derive a long-run yield response equation with respect to price. Therefore, only the sum of the lagged price coefficients was used to derive the long-run relationship between yield and price; the trend and $E(Y_{t-1})$ terms were truncated and combined with the intercept.

The long-run acreage and yield equations were multiplied together to get a long-run supply equation defined with price as the independent variable. Expected quantity of wheat produced for given values of the state variables is calculated from the relevant acreage and yield equations with suppressed state variables, and then the long-run equation is used to calculate area under the supply curve associated with that quantity.[3] This value plus storage costs is taken as expected social cost in the calculation of $G_n(x,s,p)$. Separate yield equations, and consequently, separate long-run supply equations are used for stages $k+5$, . . . , $k+1$, and another equation for stages 1, 2, . . . , k.

The demand equation for domestic food in (5) is transformed into a long-run equation and trend is truncated at the 1976 level; the marginal effect of trend is trivial after 1976 ($t = 26$ in 1976). For an expected value of domestic food consumption, this equation provides the basis for calculating gross value of social benefits per capita, and multiplication by a suitable population figure gives aggregate value for food consumption.

The price variable in both the domestic food and livestock feed demand equations for wheat is the current average price received by farmers. We need a relationship between that price and lagged price at the Gulf, which is our state variable, and we also want this relationship to reflect the impact of exports on price. A simple linear regression was run between average market price received by farmers and lagged price at the Gulf. Then a term for exports was introduced by using an a priori estimate of the elasticity of demand for U.S. exports; the method is the same as used to get from (8) to (10). This price relationship was substituted for the price variable in each demand equation to provide an estimate of mean quantity consumed in a given usage. The resulting equation reflects both the price state variable and level of exports, which is the decision variable.

The livestock feed demand equation in (6) is already static. The two extra independent variables, besides price, are combined with the intercept by setting these variables at some representative levels; we used mean values in the time-series sample.

The demand equation for seed does not contain price, only acreage planted. Therefore, we assumed that the small amount of wheat used for seed has a gross marginal social value approximately equal to average price received by farmers during the year in which the seed is used.

Either market value or social value is calculated easily for the export demand equation because exports are the decision variable and we have the autoregressive relationship for export price given in (10). For a given level of

[3] These equations are not for the long-run, but instead, are annual adjustment equations, the derivation of which was explained in the discussion of how to suppress some of the state variables; acreage was used as the illustration.

the price state variable, (10) gives a linear demand equation for exports. We now have covered all the various components needed to estimate the expected net benefit functions, $G_n(x,s,p)$, in (12).

Optimal Fixed Storage Capacity

Thus far storage capacity restrictions have been avoided, but the optimization in (12) is tacitly subject to storage capacity constraints. Recall that wheat stocks, s, taken as the sum of current harvest and carryover from previous years, is a state variable which is known information, and exports, x, is the decision variable. Let C denote fixed storage capacity for wheat; then we impose the constraint,

$$x \geq s - C. \tag{13}$$

The constraint in (13) implies that capacity, C, is used to store wheat for domestic consumption and carryover of wheat to the following year, but none of this capacity is used for exports.

First, it must be recognized that the storage model assumes all activity within a year takes place instantaneously at a single point within the year, which makes (13) an appropriate constraint. The harvest is not completed instantaneously, nor does domestic consumption all take place at the end of the year anymore than do exports all leave the country the day after harvest. The most complicating factor of all is that common storage facilities are used for all grains, which makes a specific capacity for wheat somewhat artificial. Nevertheless, specification of (13) as a constraint in the storage model provides useful information on the economics of wheat storage.

Solution of the optimal storage problem for a given storage capacity provides a present value measure of net benefits for an initial state of the decision process. A search procedure can be used to find optimal capacity, or a few points on the functional relationship can be calculated to estimate the entire function.

Empirical Results

Most of our numerical computations were done under the specification of unlimited storage capacity because total grain storage capacity was thought to be so large that the optimal decision rule would not be affected by the existing upper limit. (The results reported below support this position.) These results are discussed before considering optimal storage capacity and distribution of benefits from storage. All dollar values reported are in 1976 dollars.

Unlimited Storage Capacity

Variable costs of storage were taken as 6¢ per bushel annually (Schienbein) and a discount rate (net of inflation) of 6% was used to calculate present values. Stocks of wheat (production plus old-crop-carryover) were allowed to assume fifteen levels, starting at 1,000 and ending at 3,800 million bushels in increments of 200 million. Last season's price at the Gulf could assume ten values, \$1.00 to \$5.50, at 50¢ intervals. Exports were permitted eleven values, 50 to 2,050 million bushels, in increments of 200 million.

Computations were performed to determine optimal exports for the fall of 1976 when the existing state was 2,800 million bushels of wheat and a price of \$4.00. Optimal exports were 1,250 and 1,850 million bushels for the domestic and world criteria, respectively. Actual exports indicated by the world criterion are extremely high by any standard, but production projected from the model for the following year also is high, which substantially reduces the value of carryover into 1977. Also, the relatively high price of \$4.00 makes marginal net benefits favorable. Marginal benefits fall at one-half the rate under the world compared to the domestic criterion.

An advantage of the Markov process dynamic programming model is the direct availability of probability distributions for the state and decision variables over time. Marginal distributions of wheat stocks and prices over time under the optimal decision rule associated with the domestic criterion are given in tables 1 and 2; expected values are given at the bottoms of the respective tables. There is a pronounced downward trend in expected price (table 2) from the initial value of \$4.00 in 1976 to \$2.16 in 1979, with some sign of recovery in 1980 and a limiting average price of \$3.14. These results suggest that even under an optimal storage policy based on the domestic criterion, depressed prices are likely through 1980 without any supply control measures by the government. As can be seen by the last row of table 1, expected wheat stocks are over 3.0 billion bushels through 1980, implying an old-crop carryover in excess of 1.0 billion bushels each year during the same period.

Under the world welfare criterion, expected

Table 1. Marginal Probabilities of Wheat Stocks under the Domestic Criterion

Stocks (mil. bu.)	Year					
	1976	1977	1978	1979	1980, . . . ,	Limit
1,000	0	0	0	0	0	.0018
1,200	0	0	0	0	0	.0107
1,400		0	0	0	0	.0390
1,600		0	0	0	0	.0923
1,800		0	0	0	0	.1519
2,000		0	0	0	0	.1878
2,200		0	0	0	.0014	.1830
2,400		0	.0015	.0006	.0048	.1425
2,600	0	0	.0073	.0044	.0318	.0943
2,800	1.00	.0255	.0719	.0447	.1469	.0550
3,000	0	.3956	.2338	.1890	.3012	.0259
3,200	.	.4499	.3481	.3488	.3194	.0109
3,400	.	.1290	.2677	.3059	.1620	.0038
3,600	0	0	.0693	.1001	.0314	.0010
3,800	0	0	.0003	.0065	.0010	.0002
Expected stock	2,800	3,140	3,200	3,250	3,100	2,140

price declines more abruptly from $4.00 in 1976, to $2.07 and $2.02 in 1977 and 1978, then increases to $2.29 and $2.44 in 1979 and 1980, respectively. The limiting price far in the future is $3.14, the same as under the domestic criterion. Expected wheat stocks under the world criterion are 2,540, 2,660, 2,860, 2,810, and 2,010 million bushels in 1977, 1978, 1979, 1980, and in the limit, respectively. These lower stocks are consistent with the implied larger export levels and lower prices under the world as compared to domestic criterion. The lower long-run expected stocks show less advantage to storage under the world criterion, an intuitively plausible result because the marginal revenue curve does not decrease as fast under the world criterion.

Table 2. Marginal Probabilities of Wheat Price at the Gulf under the Domestic Criterion

Price (1976$)	Year					
	1976	1977	1978	1979	1980, . . . ,	Limit
1.00	0	0	0	.0023	.0066	.0001
1.50	.	0	.0362	.1274	.0648	.0002
2.00	.	.0054	.3697	.4831	.4584	.0225
2.50	.	.1958	.4415	.3225	.3880	.2173
3.00	.	.5214	.1334	.0580	.0757	.3935
3.50	0	.2426	.0176	.0062	.0063	.2434
4.00	1.00	.0329	.0014	.0005	.0003	.0866
4.50	0	.0019	.0001	0	0	.0264
5.00	0	0	0	0	0	.0076
5.50	0	0	0	0	0	.0025
Expected price	4.00	3.05	2.37	2.16	2.24, . . . ,	3.14

Differences in expected old-crop carryover between the domestic and world criteria are 600, 540, 390, 290, and 130 million bushels in 1977, 1978, 1979, 1980, and the limit, respectively. The limiting expected carryovers of old-crop are 610 and 480 million bushels under the domestic and world criteria, respectively. Limiting levels of expected production, consumption, and exports under either criterion are 1,528, 727, and 801 million bushels, respectively. Production is the product of an expected yield and acreage of 31 bushels and 49.2 million acres.

The asymptotic model, which used demand and supply equations with lagged variables suppressed and replaced by the price state variable, can be viewed as a limited information decision model. It is quite useful for showing the general structure of the decision rule and other aspects of the dynamic decision problem because the associated stochastic process is stationary. The optimal decision rules are invariant over time and can be given by 2-by-2 tables for the discrete variable approximations used in the computations. This asymptotic decision rule is given in table 3 for the domestic criterion with + or − used to show the changes necessary to transform the export level to that associated with the world criterion. A + or − indicates to add or subtract 200 million bushels, and a double + requires adding 400 million bushels to get the world criterion decision rule. Perusal of table 3 shows that the decision rule for the world criterion exports higher levels at relatively high stocks and prices, and vice versa, compared to the domestic criterion.

The decision model which utilized all information available in 1976 by means of the proximate procedure described earlier will be referred to as the 1976 model to distinguish it from the asymptotic model, the decision rule for which is given in table 3. Value of the extra information provided by the proximate procedure for the 1976 model can be quantified by substitution of the asymptotic decision rule of table 3 for the separate decision rules obtained from the 1976 model in years 1976–79. The difference in expected present value of net benefits under the "optimal" and asymptotic decision rules, under a given criterion, provides a quantitative measure of the extra information. These present values were $609 million and $172 million under the domestic and world criteria, respectively, for a twenty-four-year planning period; annual amortized

Table 3. Long-Run Optimal Decision Rules for U.S. Wheat Exports

Wheat Stocks	Gulf Price Last Season (1976 $) 1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50
	(million bushels)								
1,000	50	50	50	50	50	50	50	50	50
1,200	250–	250	250	250	250	250	250	250	250
1,400	250–	450–	450	450	450	450	450	450	450
1,600	250–	450–	650–	650	650	650	650	650	650
1,800	250	450	650	650+	850	850	850	850	850
2,000	450–	450	650	850	850+	1,050	1,050	1,050	1,050
2,200	450–	650–	650	850	1,050	1,050+	1,250	1,250	1,250
2,400	450–	650	850	850+	1,050+	1,050++	1,250+	1,250+	1,450
2,600	450	650	850	850+	1,050+	1,250+	1,250++	1,450+	1,450+
2,800	650–	650	850	1,050	1,050+	1,250+	1,250++	1,450++	1,450++
3,000	650–	650	850	1,050	1,050+	1,250+	1,450+	1,450++	1,650++
3,200	650–	850–	850+	1,050+	1,250+	1,250++	1,450++	1,450++	1,650++
3,400	650	850	1,050	1,050+	1,250+	1,450+	1,450++	1,650++	1,850+
3,600	850–	850	1,050	1,250	1,450	1,450+	1,650+	1,650++	1,850+

Note: Export levels in the table are for the domestic criterion; exports under the world criterion are the same with the following exceptions: + add 200, ++ add 400, – subtract 200.

values are $48.5 million and $13.7 million. The above values are dependent on the initial state and recent history of wheat prices. If wheat prices have been near the equilibrium for an extended period, the decision rule from the asymptotic model should be nearly optimal for the existing situation, making the extra information of little value.

We know that under sufficiently high exports marginal revenues are negative, and marginal net revenues, which account for supply costs, become negative at lower exports. Therefore, we might expect that the marginal value of wheat stocks would become negative at sufficiently high stocks under the domestic criterion because the model does not allow disposal of wheat outside of the market. Marginal values of the state variables are given by the partial derivatives of the function $f(s,p)$ in (12). Discrete approximations are readily obtained from the numerical results of the dynamic programming solutions. Under the domestic criterion, the marginal value of stocks in 1976 was -30¢ per bushel, while under the world criterion the same measure was 70¢. Marginal values remain positive for all states considered under the world criterion.

The marginal value of wheat stocks becomes negative at about 2,300 million bushels under the domestic criterion for conditions in 1976, which is only about 200 million bushels more than U.S. production that year. Therefore, taking production as given, we can say that the marginal value of old-crop carryover in 1976 becomes negative at about 200 million bushels. This somewhat surprising result stems from the recent history of high prices and the associated increase in production capacity of the wheat industry, as reflected by the dynamic acreage and yield equations in (1) and (3). The asymptotic model, which assumes a recent history of prices near the equilibrium, does not show negative marginal values for stocks until they reach 3,400 million bushels, under the domestic criterion, and the same value of $4.00 for the price state variable as existed in 1976.

Storage Capacity Analysis

We approach the issue of optimal storage capacity in a rather simplified way. Suppose no storage existed and initial stocks of wheat and price were given, then we ask the question: What would be the optimal capacity to build now if capacity would never be changed again? This approach to the problem avoids treating storage capacity changes in a sequential decision framework jointly with export and storage control.

Initial stocks and price have a large influence on optimal capacity determined by this method. We could think of applying our method sequentially under the simplifying assumption that the storage facilities have infinite life, thus removing the problem of attrition in the old construction. In this framework, an upper bound on optimal fixed capacity can be estimated by taking the initial state as the largest stocks and lowest price which is

ever likely to occur. Based on the asymptotic probabilities in tables 1 and 3, together with historically experienced conditions, we chose the initial state of 3,200 million bushels and \$2.50 for stocks and price.

The asymptotic model was used to evaluate storage capacity and distributional impacts because the computations were much simpler and saved considerable computer time. We would expect that a somewhat higher storage capacity would be justified under the 1976 model.

Separate dynamic programming solutions were obtained for fixed capacities of 1,000 million to 3,000 million bushels by increments of 200 million. The present value of fixed costs of storage, for the same length of planning horizon, were calculated for each capacity level. Amortized fixed costs were taken at 16¢ per bushel annually (Schienbein). Then net present values were calculated for the various levels of capacity while taking the initial state as given. Quadratic interpolation was used to determine optimal capacity under each criterion. The results were 2,100 and 2,000 million bushels under the domestic and world criteria, respectively.

Optimal capacities are quite sensitive to the initial price specified. Actual conditions existing in 1977 were 3,200 million bushels and \$3.00, which is the same as above except price is \$3.00 instead of \$2.50. Optimal capacities under the domestic and world criteria for the 1977 conditions are 2,000 million and 1,800 million bushels, respectively. If initial conditions are set equal to the long-run equilibrium values of 2,000 million bushels and \$3.00, optimal storage capacities are 1,400 million and 1,100 million bushels.

Clearly, an economically justifiable storage capacity for wheat is substantially less than that now existing in the United States, which is near 3,000 million bushels if total grain storage is prorated according to production. In fact, expected present value of net benefits with only variable costs of storage deducted is essentially constant between 2,600 million and 3,000 million bushels capacity under either criterion.

In order to give some perspective to total gains from storage, the gain in going from 1,000 million to 2,000 million bushels capacity (the latter is near optimum) under the domestic criterion is 300 million dollars annually, given the initial state of 3,200 million bushels and price of \$3.00. The comparable figure for the world criterion is \$190 million. The base of 1,000 million bushels is about as low as would make any sense; with equilibrium consumption at 730 million, this leaves maximum capacity for old-crop carryover equal to 270 million bushels. In the context of current politics, these annual values of \$300 million and \$190 million in benefits might be compared to the subsidy to wheat farmers in direct payments which is estimated at \$600 million for the 1978 crop.

Benefit Distribution and Sensitivity Analysis

An important consideration in commodity storage programs is the distribution of benefits. In the context of U.S. wheat storage net benefits can be partitioned into components associated with domestic consumers foreign consumers, domestic producers, and storage costs. Recent theoretical literature on storage (Just et al., Turnovsky 1974, 1976) suggests that the distribution of benefits is likely to be affected by curvatures of demand and supply equations and by the nature of disturbance terms, additive versus multiplicative. Several alternative specifications were evaluated by applying the optimal decision rule from our standard model to the alternative specification.

As a point of reference, the standard model can be described as having linear domestic demand, quadratic supply (concave downward with price on the vertical axis), and linear foreign demand with lagged price taken as fixed [autoregressive price structure as given in (10)]. Domestic demand disturbances are additive while the disturbance in foreign demand is multiplicative. Supply has a combination additive/multiplicative disturbance arising from additive disturbances for separate yield and acreage equations.

The alternative specifications are: (*a*) linear supply with the same form of disturbance as in the standard model, yield was taken as fixed instead of dependent on price; (*b*) nonlinear domestic demand equations for food and livestock feed with disturbances unchanged from the standard model, the nonlinear forms were the familiar Cobb-Douglas function; (*c*) nonlinear foreign demand with the additive term in (10) replaced by a multiplicative factor of the form $\exp[-b(x - \bar{x})]$, the disturbance term was left the same as in the standard model; and (*d*) static linear foreign demand with addi-

tive instead of multiplicative disturbance, the autoregressive structure of (10) was deleted. The same elasticity of demand for U.S. exports, equal to −2.5, was used in the changed specifications of (*c*) and (*d*), above, together with the condition that mean price and exports satisfy the equation, which gave unique estimates of the two-parameter equations. Nonlinear demand equations were fitted the same way using the elasticities from the linear equations of the standard model at mean prices and quantities.

Results on the distribution of benefits under the various specifications are given in table 4 for the domestic and world criteria. These figures are measures of the change in benefits when storage capacity is increased from 1.0 billion to 2.0 billion bushels with an initial state of 3.2 billion bushels of stocks and a price of $3.00, which is the state which existed in 1977. Values in the last column are for the criterion itself; the domestic criterion leaves out foreign consumers surplus. Remember that the same decision rule was applied throughout table 4, and it is optimal for the standard model only. The units are such that the values in the table can be transformed into cents-per-bushel increase in storage capacity by merely moving the decimal one place to the left. These benefit figures are net of both fixed and variable costs of storage.

It is encouraging that the distribution of benefits is qualitatively the same across all specifications, i.e., the signs on the benefits remain unchanged, because some of the theoretical results suggest that this might not have been the case. Domestic producers clearly gain from a storage program, while domestic and foreign consumers lose, the latter apparently losing the more of the two consumer groups. Introducing some convexity into either the domestic or foreign demand curve makes the respective consumer group's benefits decline. These results are difficult to compare with those of Just and Hallam because of the different approach and emphasis of the studies, but a striking similarity in the results is that domestic producers are unequivocal beneficiaries of a wheat storage program.

Another type of sensitivity analysis was performed to evaluate the decision rules for storage decisions. The important consideration is not whether the decision rules change considerably under alternative specifications but whether these changes, large or small, have an important impact on the magnitude of the criterion being used. Our test was to calculate optimal decision rules under several specifications other than the standard model, and then use these nonoptimal decision rules in the standard model to determine the change in the criterion from its value under the optimal decision rule; this change is called opportunity loss.

The alternative specifications were linear supply, nonlinear foreign demand, static foreign demand, and three different price elasticities for foreign demand, −0.5, −4.0, and −6.0. These first three specifications are the same as described in reference to the analysis on distribution. Results of the analysis are reported in table 5. These opportunity losses are

Table 4. Distribution of Benefits under Various Specifications

Specification	Criterion	Domestic Producers	Domestic Consumers	Foreign Consumers	Variable Costs of Storage	Value of Criterion[a]
		($ million annually)				
Standard model	Domestic	353	−27	−120	26	300
	World	327	−22	−95	21	189
Linear supply	Domestic	358	−27	−120	26	305
	World	332	−22	−95	21	194
Nonlinear domestic demand	Domestic	306	−101	−120	34	171
	World	283	−91	−95	28	69
Nonlinear foreign demand	Domestic	339	−23	−226	26	290
	World	314	−18	−204	21	71
Static foreign demand	Domestic	489	−28	−184	27	434
	World	439	−25	−165	22	227

Note: Values are for an increase in storage capacity from 1.0 billion to 2.0 billion bushels and an initial state of 3.2 billion bushels of wheat stocks and a price of $3.00.

[a] The domestic criterion is the sum of columns 1 and 2 minus column 4; the world criterion is the sum of columns 1, 2, and 3 minus column 4.

Table 5. Estimated Opportunity Losses in the Sensitivity Analysis

"Erroneous" Specification	Annual Amortized Losses: Domestic Criterion	Annual Amortized Losses: World Criterion
	---- ($ million) ----	
Linear supply	0.0	0.0
Nonlinear export demand	1.1	0.7
Static foreign demand	14.9	18.5
Alternative price elasticities in foreign demand:		
−0.5	81.6	137.0
−4.0	7.7	2.6
−6.0	19.6	15.7

put in perspective by relating them to the gains from storage given in table 4 under the standard model, i.e., $300 million and $190 million for the domestic and world criterion, respectively.

Obviously, the cost is very high of using the optimal decision rule under an assumed elasticity of −0.5, when it is actually −2.5. The decision rule in the inelastic case, −0.5, tends to hold export levels constant across the two state variables of stocks and price, particularly across levels of stocks. For example, under the world criterion, exports are 650 million and 850 million bushels with probabilities 0.29 and 0.71 in the limiting probability vector; other export levels occur with essentially zero probability. As would be expected, the dispersion on price is substantially greater under this kind of decision rule compared to the optimal rule in table 3.

The other misspecifications in table 5 produce decision rules which are "reasonably good" when applied to the standard model. It would appear that a good decision rule can be obtained if we can estimate the price elasticity of foreign demand with even modest precision. If the "true" elasticity is somewhere between −1.50 and −6.0, the decision rule from the standard model is probably near optimal.

We have become somewhat skeptical of the autoregressive price relationship in foreign demand; the reasons are both logical and empirical from experience in the application (see footnote 2, for the logical basis). The results in table 5 showing the opportunity losses of using the static foreign demand specification suggest that the value of information elicited by the autoregressive model is rather nominal, $15 million and $18 million under the domestic and world criteria, respectively. Therefore, we reversed the sensitivity analysis by calculating the opportunity loss from using the decision rule in the standard (autoregressive) model in the static foreign demand model, assuming the latter is the "true" model. These opportunity losses are $75 million and $99 million annually in the domestic and world models, respectively. These results suggest a considerably higher risk associated with assuming the autoregressive as opposed to the static specification. As would be expected, the decision rule associated with the static foreign demand is much less responsive to the price state variable and nearly identical with respect to wheat stocks when compared to the decision rule of the autoregressive model reported in table 3.

Summary and Conclusions

An econometric study of the U.S. wheat industry was made to provide empirical measures to use in a stochastic sequential decision model for wheat storage. The empirical results suggest that present storage capacity which might be identified with wheat is substantially in excess of what can be justified economically. The marginal value of capacity beyond 2.5 billion bushels is near zero even when fixed costs are ignored.

U.S. wheat producers are clearly the beneficiaries of a storage program, while both domestic and foreign consumers experience losses, the latter losing more than the former. Although the curvature of demand and supply equations and the structure of the disturbances have an impact on the benefits of the various groups, the qualitative results of who benefits and loses were not changed by any of the alternative specifications considered.

The method used to incorporate the suppressed state variables in an approximate way seemed to work well and increased expected net benefits by nearly $50 million per year under the domestic criterion and $14 million under the world criterion when initial conditions were those of 1976.

In retrospect, the autoregressive price relationship used in the foreign demand equation probably should be replaced with a static equation, even though less information might be used in the decision process. Additional re-

search is being done to evaluate the choice between these two specifications.

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References

Arrow, Kenneth J. "Statistics and Economic Policy." *Econometrica* 25(1957):523–31.

Arzac, Enrique. "An Econometric Evaluation of Stabilization Policies for the U.S. Grain Market." *W. J. Agr. Econ.* 4(1979):9–22.

Bellman, Richard. *Dynamic Programming*. Princeton, N.J.: Princeton University Press, 1957.

Burt, Oscar R. *Nonstochastic Difference Equations, Distributed Lags, and Agricultural Supply*. Dep. Agr. Econ. Staff Paper 78-2, Montana State University, April 1978.

Cochrane, Willard W., and Yigal Danin. *Reserve Stock Grain Models, the World and the United States, 1975–85*. University of Minnesota Agr. Exp. Sta. Tech. Bull. 305, 1976.

Garst, Gail D., and Thomas A. Miller. "Impact of the Set-Aside Program on the U.S. Wheat Acreages." *Agr. Econ. Res.* 27(1975):30–37.

Griliches, Zvi. "Distributed Lags: A Survey." *Econometrica* 35(1967):16–49.

Gustafson, Robert L. *Carryover Levels for Grain: A Method for Determining Amounts that are Optimal under Specified Conditions*. Washington, D.C.: USDA Tech. Bull. No. 1178, 1958.

Howard, Ronald A. *Dynamic Programming and Markov Processes*. New York: Technology Press and John Wiley & Sons, 1960.

Hotelling, Harold. "The General Welfare in Relation to Problems of Taxation and of Railway and Utility Rates." *Econometrica* 6(1938):242–69.

Johnson, D. Gale, and Daniel Sumner. "An Optimization Approach to Grain Reserves for Developing Countries." *Analysis of Grain Reserves, A Proceedings*, pp. 56–76. Washington, D.C.: USDA ERS-634, 1976.

Just, Richard E., and J. Arne Hallam. "Functional Flexibility in Analysis of Commodity Price Stabilization Policy." *Proceedings of the Business and Economic Statistics Section, American Statistical Association*. Washington, D.C., 1978.

Just, R. E., Ernst Lutz, Andrew Schmitz, and Stephen Turnovsky. "The Distribution of Welfare Gains from International Price Stabilization under Distortions." *Amer. J. Agr. Econ.* 59(1977):652–61.

Konandreas, Panos A. "An Econometric Analysis of U.S. Grain Exports with Policy Implications of Price Stabilization." Ph.D. thesis, University of California, Davis, 1976.

Konandreas, Panos A., and Andrew Schmitz. "Welfare Implications of Grain Price Stabilization: Some Empirical Evidence for the United States." *Amer. J. Agr. Econ.* 60(1978):74–84.

Malinvaud, E. "First Order Certainty Equivalence." *Econometrica* 37(1969):706–18.

Massell, B. F. "Price Stabilization and Welfare." *Quart. J. Econ.* 83(1969):284–98.

Oi, W. Y. "The Desirability of Price Instability under Perfect Competition." *Econometrica* 29(1961):58–64.

Reutlinger, Shlomo. "A Simulation Model for Evaluating Worldwide Buffer Stocks of Wheat." *Amer. J. Agr. Econ.* 58(1976):1–12.

Schienbein, Allen. *Cost of Storing and Handling Grain in Commercial Elevators, Projections for 1974/75*. Washington, D.C.: USDA CED FdS-252, Feb. 1974.

Sharples, Jerry A., Rodney L. Walker, and Rudie W. Slaughter, Jr. *Managing Buffer Stocks to Stabilize Wheat Prices*. Washington, D.C.: USDA ERS Agr. Econ. Rep. No. 341, 1976.

Simon, Herbert A. "Dynamic Programming under Uncertainty with a Quadratic Criterion Function." *Econometrica* 24(1956):74–81.

Taylor, C. Robert, and Hovav Talpaz. "Approximately Optimal Carryover Levels for Wheat in the United States." *Amer. J. Agr. Econ.* 61(1979):32–40.

Theil, H. "A Note on Certainty Equivalence in Dynamic Programming." *Econometrica* 25(1957):346–49.

Thurow, Lester C. "Economics 1977." *Daedalus* 106(1977):79–94.

Turnovsky, Stephen J. "Price Expectations and the Welfare Gains from Price Stabilization." *Amer. J. Agr. Econ.* 56(1974):706–16.

Turnovsky, Stephen J. "The Distribution of Welfare Gains from Price Stabilization: The Case of Multiplicative Disturbances." *Int. Econ. Rev.* 17(1976): 133–48.

U.S. Department of Agriculture. *Grain Storage Capacity Survey*. Washington, D.C.: ASCS, Oct. 1978.

Waugh, F. V. "Does the Consumer Benefit from Price Instability?" *Quart. J. Econ.* 58(1944):602–14.

Zwart, A. C., and K. D. Meilke. "The Influence of Domestic Pricing Policies and Buffer Stocks on Price Stability in the World Wheat Industry." *Amer. J. Agr. Econ.* 61(1979):434–447.

Agricultural Comparative Advantage under International Price Uncertainty: The Case of Senegal

Cathy L. Jabara and Robert L. Thompson

This study draws upon recent theoretical contributions which have introduced uncertainty into trade theory to examine empirically the implications of international price uncertainty for agricultural comparative advantage in a small open economy assuming risk-adverse policy makers. Utilizing a price endogenous, linear programming model developed for Senegal, it is shown that Senegal's comparative advantage in the production of peanuts and comparative disadvantage in the production of cereals is less clearcut when international price risk is considered. The results suggest a trade strategy of less specialization in peanuts and greater self-sufficiency in cereals may be superior to free trade.

Key words: agricultural trade, comparative advantage, international trade policy, risk, sectoral programming models, Senegal.

The traditional theory of comparative advantage demonstrates that if every country specialized in the production and export of goods in which another country is a relatively lower cost producer, both global welfare and the welfare of each trading country would be maximized.[1] This implies that free, undistorted international trade is the first best policy for all countries to follow. However, this implication, which is derived under the assumption of perfect certainty, applies only to small trading countries which cannot influence the world market price by their individual actions. The optimum tariff argument demonstrates that a large trading country can increase its own welfare, albeit at the expense of the rest of the world, by distorting domestic prices away from the international terms of trade (Johnson). Under the assumption of perfect certainty, it is demonstrated that the optimum tariff rate for a small country is zero. However, agricultural trade is characterized by two forms of uncertainty. First, there are climatic inputs in the agricultural production process which are stochastic and not under the farmers' control. Moreover, future international prices are uncertain, known at best in a probabilistic sense.

Due to uncertainty which arises in international markets for agricultural commodities, many countries, especially LDCs, have become increasingly reluctant to accept the logic of comparative advantage and follow a free trade policy. Because prices of imported food grains are uncertain, many countries have adopted policies to distort internal prices away from the international terms of trade to increase their self-sufficiency ratios in food production. In addition, these countries have advocated international commodity programs to stabilize prices of internationally traded agricultural commodities in international fora,

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[1] In addition to its normative implications, the theory also has a positive aspect. If global welfare is maximized, each country will specialize in and export those goods in which it is a relatively low-cost producer and import those goods in which other countries are relatively lower cost producers.

such as UNCTAD-IV and the North-South Dialogue. It appears that uncertainty in international markets has become an important criterion in formulating trade policy.

Recently, several theoretical contributions in the international trade literature have examined the validity of the basic theorems of international trade under both international price and production technology uncertainty. (See Pomeroy for a review of this literature.) However, with the exception of one early study by Brainard and Cooper which examines the possibilities of export and import diversification for less developed countries in a mean-variance portfolio framework, there exist no other empirical studies which examine the implications of uncertainty for international trade policy known to the authors. Whereas Brainard and Cooper assumed that international price uncertainty was a sufficient argument for diversification, this study examines whether diversification is desirable from an economic point of view.

The principal objective of this study is to draw upon the recent theoretical contributions that have introduced uncertainty into trade theory in order to examine empirically the implications of international price uncertainty for agricultural production, consumption, and trade of a small, open economy. Specifically, the study takes as its conception of comparative advantage that mix of traded products at which expected welfare (or expected real income) is at a maximum. Under perfect certainty, and with no externalities or domestic distortions, this is that output bundle observed under free trade. The Domestic Resource Cost (DRC) methodology, which has often been employed to measure empirically comparative advantage (e.g., Pearson and Meyer), attempts to correct for domestic distortions. In this paper it is shown that under risk aversion, the expected utility-maximizing output bundle is not that generated under free trade even after correcting for domestic distortions; rather, expected utility is maximized at that output bundle which is produced when domestic prices are distorted away from the international terms of trade by the subjective cost associated with the international price uncertainty. To illustrate empirically the effect of international price uncertainty on agricultural comparative advantage, a modification of the DRC methodology is utilized here within a multiproduct linear programming framework. Bruno suggested using economy-wide programming models to measure comparative advantage. This study follows the approach of Duloy and Norton (pp. 382–86) in the use of an agricultural sectoral model for measurement of comparative advantage. Unlike the latter, this study corrects for economy-wide price distortions, e.g., through the shadow price of foreign exchange. For reasons listed in the text, least-cost spatial equilibrium models like that of Mandell and Tweeten, using financial prices rather than shadow prices of factors and foreign exchange, do not correctly estimate comparative advantage. International price risk is introduced into the objective function of the model in a manner similar to that suggested by Hazell and Scandizzo for income risk at the farm level.

Senegal, a small, open economy with one dominant export, peanut products, and one dominant import product, cereals, was chosen as the case study. Traditionally, Senegal has exported peanuts and the derivative products, oil and meal, in exchange for cereals. A number of observers have argued that this policy was consistent with Senegal's comparative advantage (e.g., CILSS). Peanut production in Senegal typically has averaged about 50% of the country's total agricultural production, and foreign exchange earnings from peanut products have averaged about 40%–50% of export earnings (Dione). At the same time, imports of cereal grains, rice, wheat, millet, and corn constitute about 35% of domestic consumption of these cereals and 52% of the value of foreign exchange earnings from peanuts.

In recent years, however, policy makers in Senegal have promoted a policy of substitution of domestic production for imports of cereals, at the expense of peanut production (République de Sénégal, Ministère du Plan). The empirical analysis focuses on the question of whether this recent change in trade strategy of Senegal is consistent with an extended concept of comparative advantage which explicitly recognizes the subjective costs (assuming risk aversion) associated with international price uncertainty.

Conceptual Framework

In this section, a simple two-sector general equilibrium model is employed to demonstrate the implications of international price uncertainty for trade policy in a small, open econ-

omy. Under the assumptions of perfect certainty, profit maximization, full employment of factors of production, and absence of externalities and domestic distortions, the optimum pattern of trade is determined by the point at which the international terms of trade equals the marginal rate of transformation between the two commodities. The country is said to have a comparative advantage in the good exported and a comparative disadvantage in the good imported *vis-à-vis* the rest of the world. Any departure from free trade will lower the welfare of the country.

To illustrate, assume that the agricultural sector of Senegal produces two commodity aggregates, peanuts (X) and cereals (Y). The production frontier for the sector is defined as

$$(1) \qquad Y_p = F(X_p),\ F' < 0,\ F'' < 0,$$

where $F'(X_p)$ represents the marginal, domestic opportunity cost of peanut production, X_p, in terms of cereal production, Y_p. The country can exchange peanuts for cereals on the international market at a price ratio, $P = P_x/P_y$, which is exogenously given (small country assumption).

Assuming balance of payments equilibrium,[2] production and consumption are linked through trade by the following relationships:

$$(2) \qquad \begin{aligned} X_c &= X_p - X_e \\ Y_c &= F(X_p) + PX_e, \end{aligned}$$

where the subscripts c refer to consumption, p to production, and e to net exports (imports if $X_e < 0$).

The objective of the country is to maximize its welfare, U, as derived from consumption of X and Y:

$$(3) \qquad U = U(X_c, Y_c),\ U' > 0,$$

where U is the welfare function for Senegal as perceived by its planners (Feder, Just, Schmitz). Under perfect certainty, the optimum point of production occurs where the terms of trade equal the marginal rate of transformation $P = -F'(X_p)$. That is, no policy intervention which distorts P can improve the welfare of the population.

To examine the implications of uncertainty in international prices, the model is modified by allowing P to be a random variable with mean $E[P] = \bar{P}$. Because export and import commodities are largely marketed through government marketing agencies which in effect administer internal prices, as in many LDCs, the risk in international prices is assumed to be perceived largely by the planners or policy makers in Senegal. It is assumed that planners in Senegal attempt to maximize expected utility, $E[U]$, from consumption of X and Y. That mix of products traded when expected utility is at a maximum is taken here to define the country's comparative advantage.

Specifically, the country seeks to maximize

$$(4) \qquad E[U(X_c, Y_c)],$$

subject to

$$X_c - X_p + X_e = 0,\ Y_c - Y_p - PX_e = 0.$$

The first-order conditions for an interior solution are[3]

$$(5) \qquad \frac{\partial E[U]}{\partial X_p} = E[U_1] + F'E[U_2] = 0,$$

$$(6) \qquad \frac{\partial E[U]}{\partial X_e} = -E[U_1] + E[U_2P] = 0,$$

where $U_1 = \dfrac{\partial U}{\partial X_c}$ and $U_2 = \dfrac{\partial U}{\partial Y_c}$. Rearranging (5) and substituting into (6), and noting that $E[U_2P] = E[U_2]\bar{P} + \text{cov}[U_2P]$ yields

$$(7) \qquad \bar{P} + \frac{\text{cov}[U_2P]}{E[U_2]} = -F'(X_p),^4$$

where $\text{cov}[U_2P]/E[U_2]$ can be interpreted as the subjective cost associated with the uncertainty in international prices. In order to make the comparison with the certainty case meaningful, it is assumed that $P = \bar{P}$ in the certainty case. Thus, it is evident that $\bar{P} \gtreqless -F'(X_p)$ according to whether $\text{cov}[U_2P] \lesseqgtr 0$.

The sign of the covariance term depends upon the loss function or risk associated with uncertainty in international prices as well as upon the relationship between U_2 and P.[5] Assuming that $X_e > 0$ (Senegal is a net exporter of peanuts), and policy makers in Senegal are risk-averse, the covariance of U_2 and P is negative. Similarly, if policy makers are risk lovers, the covariance will be positive. With

[2] This assumption is relaxed in the empirical model which follows.

[3] The second order conditions must also hold, i.e., the Hessian matrix of second order partial derivatives must be negative definite.

[4] A similar condition was obtained by Hazell and Scandizzo in their analysis of the effect of risk on producer decision making.

[5] Assuming the utility function satisfies the assumptions of von Neumann-Morgenstern utility theory, if $U_{11} < 0$, the policy makers or planners are risk-averse; if $U_{11} = 0$, they are risk-neutral; and if $U_{11} > 0$, they are risk lovers.

risk neutral policy makers, the covariance term is equal to zero.

The results indicate that under risk aversion $\bar{P} > -F'(X_p)$. That is, the expected utility-maximizing policy for a small economy confronting international price risk is not a free trade policy with the international terms of trade reflected in undistorted domestic prices. Rather, equation (7) shows that the optimum trade policy is for the domestic terms of trade to be set equal to the expected international price ratio plus the subjective risk cost. In Senegal, the internal price of peanuts relative to cereals should be set lower than the world price ratio to move producers to a point on the production possibility frontier corresponding to a greater production of cereals (less imports) and a lower production of peanuts (and exports) than in the certainty case. The distortion should be greater, the greater the risk aversion of the policy makers. To define comparative advantage when there exists international price uncertainty, the net returns from production of the export product should be lowered by the subjective cost of risk associated with variation in its export price.[6] This, in effect, shifts the excess demand schedule of the rest of the world confronted by Senegal downwards by the subjective cost.

Similarly, if P and X_e are defined in terms of cereals such that $X_e < 0$ (Senegal is a net importer of cereals) and there is uncertainty in the international price of cereals, $\mathrm{cov}[U_2P] > 0$ and $\bar{P} < -F'(X_p)$, with risk aversion. In this case, Senegal would move to a point corresponding to a larger production of cereals (less imports) than in the certainty case. This result implies that, for the measurement of comparative advantage, the international price at which the commodity can be imported should be augmented by the subjective risk cost associated with uncertainty in its price.

Empirical Model

The empirical model is first developed and validated under observed prices in Senegal and then modified appropriately to carry out the comparative advantage analysis in later sections. The specification of the basic empirical model draws upon the work of Duloy and Norton, Egbert and Kim, and others in the formulation of price endogenous, linear programming, agricultural sectoral models. (See McCarl and Spreen for a survey of this literature.) The linear programming model developed for Senegal includes regional agricultural production activities, regional demand functions and regional processing activities for agricultural products, transport activities, and import and export activities. The export commodities in the model are peanuts and cotton; import commodities include rice, millet, wheat, and corn. (For more details, see Jabara, pp. 63–92.)

A regional specification of the agricultural sector model of Senegal was formulated in order to take into account the effect of internal transport costs from production regions in the interior to the port of Dakar, the destination for the bulk of the imports into Senegal. Area planted as well as production of agricultural commodities in Senegal varies by region due to the differences in rainfall. The regions in the model are listed and the salient characteristics of each are summarized in table 1.

Production activities for each region in the model were specified to differ by level of fertilizer use and type of mechanization. Three degrees of mechanization were specified for each crop: manual, horse-drawn traction, and ox-drawn traction. Five alternative levels of fertilizer use were included for both horse-drawn and ox-drawn technologies for millet and peanuts. Irrigated crop activities using tractor power also were specified for the Fleuve.

For each production activity, standard inputs of labor and services of machinery per draft animal were defined for the crop year. Labor requirements were expressed in terms of man-days, and services of draft animals were expressed in animal-days for five periods of the agricultural year. Chemicals and extension costs were expressed in terms of CFA[7] per hectare and fertilizers in terms of kilograms of nitrogen-phosphorus-potassium (NPK) fertilizer mixture per hectare.

The resources constrained in the model include land, processing capacity, and fertilizer availability. Land was classified by region as upland, swamp, flood recession, or irrigated. Land planted to cotton, improved rice, and

[6] The same analysis applies to the case of uncertainty in production technology, where the uncertainty is reflected in the effects of weather, disease, pests, etc. In this case, the domestic cost of producing the export crop is increased by the subjective risk cost associated with domestic production uncertainty. See Jabara, chap. 2, for details.

[7] The CFA is the currency of Senegal. It is tied to the French franc at a rate of exchange of 50 CFA per French franc.

Table 1. Characteristics of Regions in Senegal Agricultural Model

Region	Total Land Area	Principal Crops	Population[c]	Annual Rainfall[d]
	(1,000 ha.)		(1,000)	(mm.)
Northern[a] Peanut Basin	4,015	millet, sorghum, peanuts	1,131	400–800
Southern Peanut Basin (Sine Saloum)	2,394	millet, sorghum, peanuts, cotton, corn	1,014	800–1,000
Fleuve	4,413	peanuts, corn, millet, sorghum, irrigated rice	532	200–400
Casamance	2,835	rice, cotton, corn, peanuts, millet, sorghum	741	1,000–1,500
Senegal Oriental	5,960	rice, cotton, corn, millet, sorghum, peanuts	288	800–1,000
Cap Vert[b]	—	—	990	—

[a] Refers to administrative regions of Thies and Diourbel.
[b] This region comprises the Dakar area, which is primarily urban.
[c] Source: Vth Plan. Population figures are for 1976.
[d] Rainfall in Senegal is concentrated largely in the months from June–November.

corn in the Southern Peanut Basin was constrained at the levels for 1975/76 because the production of these crops is controlled by government programs. Fertilizer access was also constrained in the model because it is available only to farmers who are members of the cooperatives.

Two types of labor were supplied in the model by region: domestic family labor and *navetanes*. The *navetanes* are seasonal laborers who come to Senegal from Mali or Guinea Bissau and remain for the duration of the cropping season (May to November). Both types of labor were assumed to be supplied at a constant cost charged to the objective function (i.e., infinitely elastic supply assumed). For *navetanes* this charge is the yield of a hectare of land planted in peanuts times the producer price, plus food for the cropping season. For family labor, one-half of the market wage rate per man-day times the number of man-days supplied in each year was entered into the objective function as a reservation wage.

Separate demand functions for all products were specified for the urban and rural populace. About 80% of domestic production of cereals is consumed on the farm in Senegal. However, due to a lack of data with which to estimate on-farm demand functions, home consumption was taken as exogenously given at observed levels. For urban consumers, downward sloping demand functions were estimated.

Econometric estimates of urban demand functions for millet, rice, and peanut oil were made by Jabara. These price elasticities, estimated through a constant elasticity (log-linear) formulation, were -1.25 for peanut oil, -0.75 for rice, and -0.48 for millet. Price elasticities of demand for maize and wheat could not be estimated due to data deficiencies. However, because the demand characteristics of the cereals are similar in Senegal, the same estimated price elasticity was used for wheat and rice. Similarly, the same estimated price elasticity was used for millet and maize. Cross-price elasticities were not included because they could not be estimated and there exist no estimates known to the authors. It was assumed that the urban price and income elasticities of demand for each cereal are the same in all regions. A price elasticity of -0.3, obtained for the Ivory Coast, was used for cotton (Vaurs, Goreux, Condos).

The objective function of the model was specified to simulate a competitive market equilibrium where price equals marginal cost for each production activity. The objective function, which is maximized, equals the sum of the areas under the domestic demand schedules, plus the value of exports, less the cost of imports, processing, input supply, and transport. (The cost associated with international price risk is introduced later in the comparative advantage under risk section.) The objective function was specified under the behavioral assumption that the micro units which comprise the Senegalese agricultural sector are profit maximizers.

Model Validation

The solution values for area planted, production, imports, and exports in the model are presented in table 2. For the purpose of validation, table 2 compares the model solutions for these variables to observed, annual values for 1973/74–1975/76. For brevity, the regional solutions are aggregated into country totals for Senegal. (See Jabara, pp. 96–101 for regional detail.) All prices in this specification of the model are the observed prices in 1975/76. These are the exogenously given world prices (small country assumption) as distorted by existing policy interventions in Senegal. These distortions include export taxes on peanut products as well as a consumer tax on imported rice which acts to make domestic production of rice more competitive with imports in certain regions of the country. The producer price of irrigated rice is also subsidized in the Fleuve region.

In general, the basic specification of the model appears to replicate, reasonably, observed conditions in Senegal. For crop production and area planted, the percentage deviations of the model solutions from the observed values are quite small. The largest deviation is for cotton production. Export volumes generated by the model are overstated in every case. This result is due, in part, to the constraint that at least 80% of peanut production would be marketed by farmers. The remaining 20% represents losses, seed, home consumption, and sales to the unofficial market. The actual percentage may be less.[8]

A lower bound was imposed on millet imports at the level of imports for 1975/76 because, at the prices in the model, it is profitable to supply all domestic millet consumption from domestic production. In reality, Senegal imports small quantities due to internal marketing problems.

Comparative Advantage under Price Certainty

Chenery has argued that the optimum pattern of trade is defined by comparing the opportunity cost of producing a given commodity with the price at which the commodity can be exported or imported, after correcting for any price distortions in the economy. In this case, the relevant cost of production of each commodity equals the value of the factors of production used to produce it, as measured by shadow prices, which reflect the true scarcity values of the factors to the economy. The essence of the DRC method of analysis of comparative advantage is to compare the domestic cost of production (measured by shadow prices) with the international price at which the commodity is exported or imported (Pearson and Meyer).

The DRC approach tends to be partial, and it ignores substitution effects in production. In contrast, the approach employed here is to adapt the multicommodity programming model described in the previous section to analyze agricultural comparative advantage in Senegal. The programming model, in whose solution all commodities are produced in their relatively least-cost location, represents an improvement upon the Domestic Resource Cost technique by explicitly taking account of factor substitution.

In order to analyze agricultural comparative advantage in Senegal, all prices in the basic model were adjusted to correct for domestic price distortions which arise from policies of the Senegalese government. In order to cor-

[8] This discrepancy is partly due to the fact that the data on production and exports come from two different sources which are not necessarily consistent. International trade statistics are readily available in Senegal, and the quality of the data is quite good. Production data are more difficult to obtain, and the information is of a lower quality.

Table 2. Senegal Agricultural Sector Model Validation Results, 1975/76

	Model Results	Observed Value	Percentage Error
Area planted	(1,000 Hectares)		
Peanuts	1,105.7	1,120.2	−1.3
Millet	1,074.3	1,047.5	2.5
Maize	61.5	57.1	7.6
Cotton	39.2	41.1	−4.6
Rice	87.8	82.4	6.6
Production	(1,000 Metric Tons)		
Peanuts	1,046.1	1,044.0	0.2
Millet	653.2	661.4	−1.2
Maize	51.8	48.7	6.4
Cotton	46.8	37.5	24.6
Rice	117.2	123.8	−5.3
Exports	(1,000 Metric Tons)		
Peanut oil (crude)	200.3	153.6	30.3
Peanut oil (refined)	36.8	30.0	22.5
Peanut meal	334.7	283.1	18.2
Raw cotton	12.6	7.9	59.9
Imports	(1,000 Metric Tons)		
Rice	161.6	170.9	−5.4
Wheat	90.3	99.4	−9.1
Maize	4.1	6.1	−32.0
Millet	6.0	6.0	0.0

rect for these distortions, all material inputs of production were valued at the supply cost to Senegal, adjusted for taxes. The foreign exchange component of the cost of material inputs, as well as the c.i.f. and FOB prices of imports and exports, respectively, were converted into domestic currency units by the shadow price of foreign exchange. The shadow price estimated for this study indicates that the CFA was overvalued by 13%. Capital expenditures were also evaluated at the shadow interest rate for Senegal. These latter shadow prices, for foreign exchange and capital, were assumed to be economy-wide estimates of the appropriate values. Shadow prices for land and labor were generated endogenously by the model. Activities for interregional trade were also included in the comparative advantage formulation (see Jabara, pp. 110–22, for details).

The results of the comparative advantage analysis under price certainty are presented in table 3 and compared to the base case from table 2. The results of table 3 indicate that at the "adjusted" prices, Senegal has a comparative advantage in the production and export of peanuts and a comparative disadvantage in the production of cereals. In the comparative advantage solution, the area planted to peanuts increases by 11% over the base model result. Area planted in all crops, as well as production of cereals, declines relative to the base solution. As a result of these changes, exports of peanuts and imports of cereals increase relative to the base model. Thus, in the comparative advantage solution, Senegal moves to a point on its production frontier which is more specialized in the production and export of peanuts than in the base case in which prices are distorted.

The relatively small magnitudes of the changes in production and trade in table 3 are due to the assumption made in the model that imports supply only urban areas and that the farm population produces all of its own consumption. However, the direction of the change is the important indicator of the direction of comparative advantage for Senegal with undistorted prices.

The largest change is in the area planted and production of rice, which decreases by about 22%. This change reflects the comparative disadvantage of Senegal in the production of rice and the relatively large urban demand for rice.

Table 3. Model Solutions for Comparative Advantage Case, Compared to the Base Model, Senegal, 1975/76

Activity	Comparative Advantage Solution	Base Solution	Percent Change
Area Planted	----- (1,000 Hectares) -----		
Peanuts	1,224.7	1,105.7	11.0
Millet	970.0	1,074.3	−9.7
Maize	60.6	61.5	−1.4
Cotton	36.8	39.2	−6.2
Rice	68.9	87.8	−21.5
Production	---- (1,000 Metric Tons) ----		
Peanuts	1,152.3	1,046.1	10.1
Millet	599.3	653.2	−8.2
Maize	50.5	51.9	−8.2
Cotton	46.9	46.8	0.3
Rice	91.0	117.2	−22.4
Exports	---- (1,000 Metric Tons) ----		
Peanut oil (crude)	228.2	200.3	13.9
Peanut oil (refined)	36.8	36.8	0.0
Peanut meal	368.0	334.7	10.0
Cotton	13.4	12.6	6.5
Imports	---- (1,000 Metric Tons) ----		
Rice	214.3	161.6	32.6
Wheat	90.3	90.3	0.0
Maize	5.2	4.1	27.0
Millet	53.5	6.0	790.9

Comparative Advantage under Price Uncertainty

The above analysis of comparative advantage assumes perfect certainty in international prices which are reflected undistorted into the Senegalese economy. However, as illustrated in table 4, which presents the means, standard deviations, and coefficients of variation for the traded crops in Senegal, it is evident that there exists considerable uncertainty in the international prices confronted by Senegal. This table suggests that rice, which has the highest coefficient of variation of all of the commodities, is the riskiest commodity to import in terms of price variability. The coefficients of variation for peanut products are also high relative to the coefficients of variation of other cereals (except rice) and cotton prices. Based upon this evidence and with the additional assumption of risk aversion of economic policy makers, a trade strategy based upon exports of peanut products in exchange for rice may not be the most desirable trade strategy for Senegal.

Hazell and Scandizzo have shown that when risk is included on the supply side in the

Table 4. Means, Standard Deviations and Coefficients of Variation for International Prices of Traded Commodities, Senegal, 1968–1976

Commodity	Mean Price	Standard Deviation of Price[a]	Coefficient of Variation[b]
Imports	----	(1,000 CFA/ton)	----
Millet	22.6	3.9	.17
Wheat	28.5	5.4	.19
Maize	24.7	2.5	.10
Rice	43.0	18.1	.42
Exports	----	(1,000 CFA/ton)	----
Peanut oil (crude)	118.7	40.6	.34
Peanut oil (refined)	135.7	37.2	.27
Peanut meal	27.1	6.2	.23
Peanuts	76.7	20.9	.27
Cotton	214.3	37.4	.17

[a] Estimated as the standard error of the estimate from a linear regression of the form $Y = a + bt$ where Y = international price, t = time, and a and b are the estimated regression coefficients.
[b] The coefficients of variation in this table may overstate the uncertainty in international prices due to unusually large price increases in 1973.

objective function of such a sector model, the marginal cost schedule for risky activities is shifted to the left by the subjective cost of risk associated with the activity. In the international price uncertainty context, this implies that the excess supply schedule of the rest of the world is shifted upward, i.e., the cost of importation is increased by the subjective cost of risk associated with variation in import prices. On the export side, international price risk implies that the returns to exporting the product are decreased by the subjective cost associated with variation in export prices.

Risk is incorporated into the Senegal agricultural sector model through an $(E, \phi\sigma)$ utility formulation (Hazell and Scandizzo, Simmons and Pomerada).[9] In the Hazell and Scandizzo formulation, the relevant decision makers are taken to be the farmers who base their production decisions on expected income less the subjective cost of risk associated with the income-producing activity. In this present application, the relevant decision makers are the policy makers in Senegal who administer domestic prices and determine how far to distort internal prices away from the international terms of trade. The expectations operator, E, refers to expected world price, σ to the standard deviation of that price, and ϕ is the subjective risk coefficient, which measures the degree of risk aversion of the decision makers.

With the additional assumptions of risk aversion and international price variability, the microunits which comprise the sector are assumed to produce where price received equals marginal cost. However, the internal prices which the producers face are lowered (raised) by the policy makers relative to international prices by the cost of risk that they associate with export (import) prices. This approach assumes that policy makers can effectively fix domestic prices to reflect the perceived cost of risk to the economy. In Senegal this is accomplished by fixing the price at which the official marketing agency, *Office Nationale de Coopération et d'Assistance pour le Développement* (ONCAD) purchases peanuts and cereals. Although there exists some trading on unofficial markets, especially in the case of millet and maize, the official prices serve as guaranteed prices and unofficial prices tend to align themselves around these levels (*Société d'Études de Développement Nationale*).

The measure of variability in international prices used in the model was the standard deviation as estimated from the mean absolute deviation (Hazell). Separate standard deviations were estimated for the portfolios of export prices and import prices. Following Brainard and Cooper, it was assumed that planners would prefer export prices to be negatively correlated with each other and import prices to be negatively correlated with each other. To reflect this in the model, separate measures of import and export price variability had to be included.

The standard deviations of import and export prices during 1968–76, the period for which data were available, were calculated on FOB prices for exports and c.i.f. prices for imports in Senegal. The data were detrended using linear regressions of prices against time, in order to account for systematic variations in international prices.

The risk coefficient, ϕ, is assumed to be a suitable average of the subjective risk cost across traded commodities as perceived by policy makers in Senegal. In principle, the planners' utility function could have been elicited and the value of ϕ empirically estimated (Anderson, Dillon, Hardaker, chap. 4). However, lacking resources for this purpose, alternative solutions of the model were obtained by parametrically varying ϕ from 0 to

[9] Simmons and Pomerada used the standard deviation, σ, as the measure of uncertainty, whereas Hazell and Scandizzo suggested the use of the variance σ^2.

2.5, the most common values used in the literature (Hazell et al.).

Table 5 gives the model results for analysis of comparative advantage under price uncertainty for Senegal. At a value of $\phi = 0$, the comparative advantage solution presented in table 3 is obtained. Larger values of ϕ represent greater degrees of risk aversion of the policy makers in Senegal. While the value of ϕ was not estimated empirically, the larger values of ϕ appear to be more consistent with the stated objectives of policy makers in Senegal.

The results of table 5 suggest that Senegal's comparative advantage in peanuts *vis-à-vis* cereals is less clear-cut when uncertainty in international prices and risk aversion are introduced. As the degree of risk aversion, as measured by ϕ, increases, production and exports of peanuts decrease relative to the comparative advantage ($\phi = 0$) case. At the same time, production of millet, maize, and rice increase relative to the comparative advantage case. Imports of all cereals decrease. The decrease in wheat imports is relatively smaller because Senegal, at present, produces virtually no wheat. The decrease in imports is caused by the subjective price increase associated with uncertainty in the international price of wheat.

At the higher value of ϕ in table 5, Senegal becomes self-sufficient in millet and maize in the interior of the country, but imports remain the least-cost source of supply to the port region, the Cap Vert. This result indicates that even with international price uncertainty, it remains socially profitable for Senegal to import cereals for consumption near the port because of high internal marketing costs. Imports remain the least cost source of supply of rice to all regions of the country.

Table 5. Comparative Advantage Solutions under International Price Uncertainty, Senegal

	Degree of Risk Aversion		
Commodity	$\phi = 0.5$	$\phi = 1.5$	$\phi = 2.5$
Imports		(1,000 Metric Tons)	
Rice	212.8	197.7	183.6
Wheat	90.3	90.3	88.3
Millet	45.4	25.9	16.0
Maize	4.7	4.1	3.5
Exports		(1,000 Metric Tons)	
Peanut oil (crude)	215.2	188.1	183.4
Peanut meal	352.5	320.1	314.5
Peanut oil (refined)	36.8	26.8	26.8
Cotton	13.3	12.9	12.9
Area planted		(1,000 Hectares)	
Peanuts	1,208.7	1,087.0	1,070.7
Millet	984.4	1,105.0	1,117.7
Maize	36.8	35.7	35.7
Cotton	60.3	61.8	61.5
Rice	68.9	71.3	74.8

The largest percentage increase in area planted as ϕ increases is in millet production. This increase in millet production is largely caused by the decrease in profitability of peanuts relative to millet associated with the greater uncertainty in the international price of peanut products. Thus, risk, in effect, distorts the domestic perception of the international terms of trade of peanuts in terms of millet towards a price ratio that is more favorable for millet and less favorable for peanuts.

Although international rice prices have the largest coefficient of variation, the increase in rice production is not as large as for millet as ϕ increases. This result is due to the large comparative disadvantage of Senegal in rice production when evaluated at world prices. Maize production does not increase to any large extent in the international price risk solutions because at $\phi = 0$, Senegal is basically self-sufficient in maize production with the exception of the region near the port which imports maize.

In the larger study (Jabara), domestic yield, as well as international price uncertainty, were introduced into the comparative advantage analysis. These results indicated that when both sources of uncertainty are considered, the pattern of comparative advantage is less clear cut. Instead, comparative advantage depends upon the relative weights the planners associate with the risk from the different sources. Uncertainty in the domestic yields of all crops in effect shifts their supply schedules upward. Uncertainty in international prices shifts the rest of the world's excess demand schedules for exports downward, and excess supply schedules for imports, upward. Therefore, uncertainty in both yields and world prices of exportable crops works in the same direction to reduce exports, but uncertainty in both yields and world prices of importable crops works in opposite directions. In Senegal, where stated policy promotes import substitution, it appears that policy makers place a lower weight on yield uncertainty for import substitute crops than on international price uncertainty.

Conclusions and Policy Implications

This study has attempted to analyze empirically the comparative advantage of a small,

open economy under the assumption of aversion of economic policy makers to international price risk. The results of the empirical analysis, which includes international price risk, show that a country may be better off at a more diversified position than would be prescribed by a conventional comparative cost analysis. That is, free, undistorted trade may not be the first best policy for all small countries to follow. Domestic import substitution programs, such as the one pursued by Senegal, may be preferable to free, undistorted trade when risk aversion is taken into account. Such programs may indeed be consistent with a broader concept of comparative advantage which recognizes that risk has a subjective cost.

The results of the analysis also suggest that a small trading country in an uncertain environment can increase welfare by distorting internal prices away from the international terms of trade. In Senegal, policy interventions lower the internal prices of the export products, peanuts and cotton, and raise the internal prices of cereals. The analysis presented here suggests that in the presence of international price uncertainty Senegal was made better off by producing more cereals at the expense of peanuts. Government policies which distort internal prices away from international prices to reflect the cost of risk to the economy, as perceived by policy makers, may be superior to free trade from an economic point of view.

In addition, to the extent that many LDCs act simultaneously to implement import substitution programs, the rest of the world will be made worse off.[10] Moreover, if these countries impose quantitative restrictions or otherwise cut the link between domestic and international prices as suggested here, greater price instability will result in international markets. This suggests that commodity agreements or other schemes designed to stabilize world commodity prices could play an important role in promoting greater international trade among countries as a result of reducing international price uncertainty.

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[10] It is assumed that the small trading country assumption applies to each LDC individually, i.e., no one country's actions alone can affect the international terms of trade. However, if many LDCs simultaneously impose trade restricting policies, their combined actions would affect world market prices.

References

Anderson, Jock R., John L. Dillon, and Brian Hardaker. *Agricultural Decision Analysis.* Ames: Iowa State University Press, 1977.

Brainard, William C., and Richard N. Cooper. "Uncertainty and Diversification in International Trade." *Food Res. Inst. Stud.* 8(1968):257–85.

Bruno, Michael. "Optimal Selection of Export Promoting and Import Substituting projects." *Planning the External Sector: Techniques, Problems and Policies,* pp. 88–135. New York: United Nations, 1967.

Chenery, Hollis B. "Comparative Advantage and Development Policy." *Amer. Econ. Rev.* 51(1961):18–25.

CILSS Club du Sahel. "Senegal." *Marketing, Price Policy, and Storage of Food Grains in the Sahel,* vol. II, Country Studies. Ann Arbor, Mich.: Center for Research and Economic Development, 1977.

Dione, Josue. "Le Deficit Cerealier au Senegal: Situation et Perspectives." Centre Nationale de Recherches Agronomiques de Bambey, 1975.

Duloy, John H., and Roger D. Norton. "CHAC: A Programming Model of Mexican Agriculture." *Multi-Level Planning Case Studies in Mexico,* eds. L. M. Goreux and Alan S. Manne, pp. 291–337. Amsterdam: North-Holland Publishing Co., 1973.

Egbert, Alvin C., and H. M. Kim. *A Development Model for the Agricultural Sector of Portugal.* World Bank Staff Occas. Pap. No. 20. Baltimore, Md.: Johns Hopkins University Press, 1975.

Feder, Gershon, Richard Just, and Andrew Schmitz. "Storage with Price Uncertainty in International Trade." *Int. Econ. Rev.* 18(1977):553–68.

Hazell, Peter B. R. "A Linear Alternative to Quadratic and Semi-Variance Programming for Farm Planning under Uncertainty." *Amer. J. Agr. Econ.* 53 (1971):53–62.

Hazell, Peter B. R., and P. L. Scandizzo. "Competitive Demand Structures under Risk in Agricultural Linear Programming Models." *Amer. J. Agr. Econ.* 56 (1974):235–44.

Hazell, P. B. R., R. D. Norton, M. Parthasarathy, and Carlos Pomareda. *The Importance of Risk in Agricultural Planning Models.* Washington, D.C.: International Bank for Reconstruction and Development. World Bank Staff Work. Pap. No. 307, 1978.

Jabara, Cathy L. "Agricultural Comparative Advantage under Uncertainty: The Case of Senegal." Ph.D. thesis, Purdue University, 1979.

Johnson, Harry G. "Optimum Welfare and Maximum Revenue Tariffs." *Rev. Econ. Stud.* 19(1950–51): 28–35.

Mandell, Paul I., and Luther G. Tweeten. "The Location of Cotton Production in the U.S. under Competitive Conditions: A Study of Crop Location and Comparative Advantage." *Geographical Rev.* 3(1971):334–53.

McCarl, Bruce A., and Thomas H. Spreen. "Price Endogenous Mathematical Programming as a Tool for Sector Analysis." *Amer. J. Agr. Econ.* 62(1980): 87–102.

Pearson, Scott R., and Ronald K. Meyer. "Comparative Advantage among African Coffee Producers." *Amer. J. Agr. Econ.* 56(1974):310–13.

Pomeroy, John. "Uncertainty and International Trade." *International Economic Policy: Theory and Evidence*, eds. Rudiger Dornbush and Jacob A. Frenkel, pp. 112–56. Baltimore, Md.: Johns Hopkins University Press, 1979.

Senegal, Républic du Ministère du Plan et de Coopération. *V^th Plan Quadriennial de Développement Économique et Social, 1977–81*. Dakar: Ministère du Plan, 1977.

Simmons, Richard L., and Carlos Pomareda. "Equilibrium Quantity and Timing of Mexican Vegetable Exports." *Amer. J. Agr. Econ.* 57(1975):472–79.

Societé Nationale d'Études de Développement. *Etude sur la Commercialisation et le Stockage des Cereals au Sénégal.* Dakar: Societé Nationale d'Études de Développement, 1977.

Vaurs, R., L. Goreux, and A. Condos. "An Agricultural Model from the Ivory Coast Programming Study." Washington, D.C.: International Bank for Reconstruction and Development, Econ. Staff Work. Pap. No. 125, 1972.

Mitigating the Effects of Multicollinearity Using Exact and Stochastic Restrictions: The Case of an Aggregate Agricultural Production Function in Thailand

Ron C. Mittelhammer, Douglas L. Young, Damrongsak Tasanasanta, and John T. Donnelly

Ordinary least squares, exactly restricted OLS, stochastically restricted OLS (mixed estimation), and principal components regression each were used to estimate an aggregate agricultural production function for Thailand for which data were highly multicollinear. Pretest considerations, incorporating alternative risk measures, were addressed in detail for purposes of model evaluation. The final mixed and principal components models generally outperformed OLS in terms of risk and overall reasonableness, mitigating a serious multicollinearity problem and permitting a direct examination of the rate and composition of Thai agricultural output growth.

Key words: biased estimation, multicollinearity, production function, Thailand agriculture.

In recent years econometricians have made substantial progress in developing alternatives to ordinary least squares (OLS) regression techniques that have the potential for mitigating the effects of multicollinearity. These alternatives have included ridge regression (Hoerl and Kennard), principal components regression (Hill, Fomby, Johnson; Mittelhammer and Baritelle; Hill and Fomby), exact linear restrictions (Goldberger), Bayesian econometrics (Zellner), and mixed estimation (Theil and Goldberger). Although these estimating techniques may produce biased estimates, their advocates have demonstrated that they can achieve substantial reductions in mean square errors under appropriate circumstances. The theoretical progress in development of biased alternatives to OLS regression procedures has been accompanied by development of the statistical properties of pretest estimators in regression analysis (Bock, Judge, Yancy; Brook; Wallace).

In spite of the immediate relevance of these theoretical developments to applied economists, there has been relatively little consideration of either biased regression techniques or pretest implications in applied econometric research. Notable exceptions in the agricultural economics literature are the studies by W. Brown, Brown and Beattie, and Moscardi and de Janvry, which used ridge regression to estimate production functions, and the studies of Holloway, Mittelhammer and Price, and Price and Mittelhammer which use the mixed estimator.

The purpose of this paper is to evaluate in an applied study the use of three alternative regression techniques to mitigate the effects of serious multicollinearity and also to discuss the implications of pretest considerations. The techniques are applied to the estimation of an aggregate agricultural production function for Thailand using time-series data from 1950 to 1976 (see Tasanasanta). The alternatives to OLS which are examined include OLS regression with exact linear restrictions, mixed estimation (or regression with stochastic linear restrictions), and principal components regression (PCR). A pretest estimator can be implied in the use of each of the techniques

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utilized, and pretest considerations are addressed in the discussion that follows.

Aggregate Production Function Estimation and Agricultural Growth Measurement

Attempts to estimate aggregate production functions have been plagued by high correlations among explanatory variables since the pioneering work of Cobb and Douglas five decades ago. Serious multicollinearity typically reduces the precision of parameter estimates to the point where confidence in their signs and magnitudes is very low. Compounding the multicollinearity problem have been efforts to measure technological advance in the aggregate production process by using some function of time as a proxy. Aggregate measures of land, labor, and capital inputs tend to be highly correlated with each other and with time. Murray Brown (p. 112) has cited this problem as a major obstacle to measuring technological progress by directly estimated aggregate production functions.

In the current application, the use of alternative regression techniques to overcome extreme multicollinearity among aggregate input levels and time made possible a more useful decomposition of the sources and rates of growth in real Thai agricultural output during the period 1950–76. The specific objectives of this analysis are twofold: (*a*) to obtain accurate estimates of production elasticities for land, labor, capital, and technology in Thai agriculture in order to decompose 1950–76 agricultural growth between neutral technological progress and increased use of conventional inputs; and (*b*) to test the hypothesis that three government-sponsored economic planning periods between 1961 and 1976 had no discernible impact on the rate of any neutral technological progress in the agricultural sector.

It should be noted that determining the contribution of technological progress to output growth by direct estimation of the underlying aggregate production function has some strong theoretical advantages over the commonly used index number approach pioneered by Solow. (See Nevel for an application of the Solow approach to the U.S. agriculture sector.) Use of the Solow method requires assuming both constant returns to scale and perfectly competitive equilibrium (i.e., all inputs are being paid their marginal value products), but these two strong assumptions can be relaxed if it is possible to estimate the aggregate production function directly. As illustrated in figure 1, the proportionate contribution of neutral technological progress ($\Delta Q_T/\Delta Q$) and of conventional input expansion ($\Delta Q_I/\Delta Q$) can be calculated straightforwardly by decomposing output growth (ΔQ) over t_0 and t_n between a movement along the beginning year production function and the shift between base and ending year production functions.

Thai Agricultural Growth Experience

As the largest sector of the Thai economy, agriculture currently provides one-third of the GDP, 70% of export earnings, and employment for 78% of the total labor force (Ministry of Agriculture and Cooperatives; Sriplung). The critical role of agriculture in generating foreign exchange was accentuated by the marked reduction of capital inflows associated with the withdrawal of American troops during the early 1970s and by continuing deficits in the balance of trade (Ministry of Agriculture and Cooperatives). Within Thailand, the importance of the agricultural sector has been recognized by increased budget allocations over time to the Ministry of Agriculture and Cooperatives and an explicit focus on agriculture in recent government planning periods (Tasanasanta).

In spite of Thailand's generally accepted, promising, agricultural potential, there is a widespread feeling that actual performance has fallen short of that potential. This view is based largely on the observed relatively slow rate of adoption of the new high yielding varieties (HYVs) of rice and the related minimal impact of the "Green Revolution" in Thailand as compared to certain other Asian countries

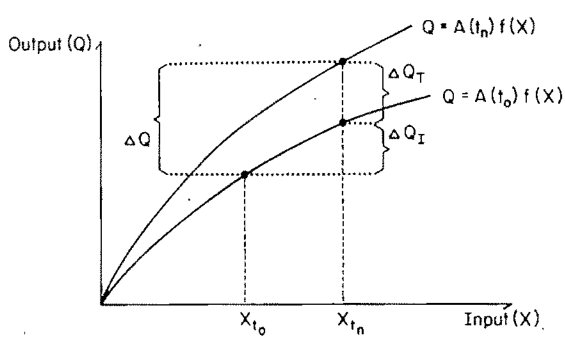

Figure 1. Contributions of neutral technological progress (ΔQ_T) and of input expansion (ΔQ_I) to total growth in output (ΔQ)

(Griffin, pp. 41–43; Myint, chap. 2). This phenomenon has been attributed to both environmental and administrative constraints. First, as is well known, a necessary condition for realizing the yield potential of the HYVs of rice is water control facilities or exceptionally well-distributed rainfall (B. Johnston, pp. 397–80). In Thailand, the lack of flood control facilities has constrained the adoption of the short-stemmed HYVs in the deep-flooding river basins, while inadequate irrigation development has limited adoption in the Central Plains (Griffin; Hsieh and Ruttan). Second, and more generally, in Thailand a scarcity of effective agricultural research and extension resources, together with high input costs, incentive-weakening commodity price policies, and infrastructural and administrative deficiences may have seriously limited the realization of productivity gain potentials in agriculture (Silcock).

In view of these widespread predominantly qualitative speculations on agricultural productivity trends in Thailand, a quantitative examination of the sources and rates of agricultural growth, and the impact of government planning periods on that growth, appeared to be justified.

OLS Model and Results

A variant of the Cobb-Douglas production function which permits a constant rate of neutral technological progress was selected.[1] Upon modification to permit differential productivity growth between government planning periods, the specification became

$$(1)\quad Q = Ae^{t(\alpha_0+\alpha_1D_1+\alpha_2D_2+\alpha_3D_3)}L^{\beta}N^{\gamma}K^{\sigma}e_u,$$

where Q is aggregate agricultural output in billion baht at constant 1956 prices, including crops, livestock, fishery, and forestry output; A is a constant; t is time, 1, 2, . . . , 27; L is land input, harvested acreage in million rai; N is agricultural labor force in million workers; K is agricultural capital in billion baht at constant 1956 prices; D_1 is 1 in 1961–66, 0 elsewhere, representing first government planning period; D_2 is 1 in 1967–71, 0 elsewhere, representing second government planning period; D_3 is 1 in 1972–76, 0 elsewhere, representing third government planning period; and u is the error term.

Given a value of t, the production function is conditionally homogeneous of degree $(\beta + \gamma + \sigma)$ in land, labor, and capital. The time variable $e^{t(\alpha_0+\alpha_1D_1+\alpha_2D_2+\alpha_3D_3)}$, is introduced as a proxy for neutral technological change. The rate of technological progress is $(\partial Q/\partial t)/Q = \alpha_0 + \alpha_1D_1 + \alpha_2D_2 + \alpha_3D_3$.

Taking the natural logarithm of both sides of equation (1), the following estimating equation for the production function was obtained:

$$(2)\quad \ln Q = \ln A + \alpha_0 t + \alpha_1 D_1 t + \alpha_2 D_2 t + \alpha_3 D_3 t + \beta \ln L + \gamma \ln N + \sigma \ln K + u.$$

Examination of the simple and multiple correlations involving regressors in (2) indicated that a serious multicollinearity problem existed. Selected squared multiple correlations are presented in table 1. (See J. Johnston, p. 163, on the usefulness of multiple correlations in detecting multicollinearity.)

Pure estimation of the highly multicollinear model in (2) using ordinary least squares revealed the characteristic symptoms of imprecise estimation of the parameters of the model (see model 1 results in table 2). All but two of the parameter estimates are judged insignificant by the standard t-test at the .05 level of type I error ($t_{.05,\ 19\ df} = 2.093$). The extremely high estimated elasticity on the labor variable which indicates a 3.23% increase in output for a 1% increase in labor seems particularly unreasonable.

A simultaneous test of the hypothesis that all three coefficients associated with the government-planning period dummy variables

Table 1. Selected Multiple Correlations Involving Independent Variables

Dependent Variable	Regressed On	R^2
$\ln L$	$\ln N$, $\ln K$, t	.952
$\ln L$	$\ln N$, $\ln K$, t, D_1t, D_2t, D_3t	.964
$\ln N$	$\ln L$, $\ln K$, t	.995
$\ln N$	$\ln L$, $\ln K$, t, D_1t, D_2t, D_3t	.998
$\ln K$	$\ln L$, $\ln N$, t	.990
$\ln K$	$\ln L$, $\ln N$, t, D_1t, D_2t, D_3t	.998
t	$\ln L$, $\ln N$, $\ln K$	.997
t	$\ln L$, $\ln N$, $\ln K$, D_1t, D_2t, D_3t	.999

[1] The many limitations of the simple Cobb-Douglas form and the assumption of neutral technological progress have been well documented in the literature, e.g., see Murray Brown. However, given the limited adoption of the "Green Revolution" technologies in Thai agriculture, the assumption of neutral technological progress seemed reasonable in this initial investigation. This easily manageable specification also facilitated comparisons of the estimation techniques whose evaluation was a principle objective of this research.

Table 2. Production Function Results Using Alternative Estimation Techniques

Model No.[a]		Estimated Coefficient of										
	$\ln A$	$\ln L$	$\ln N$	$\ln K$	t	D_1t	D_2t	D_3t	$D-W$	R^2	F	$P(F(m, n; .5) > c)$
1	−4.5108	0.4937	3.2300	0.1668	−0.0553	−0.0036	−0.0022	0.0018	1.683	.988		
		(2.74)[b]	(2.86)	(0.38)	(−1.86)	(−0.88)	(−0.33)	(0.25)				
2	−1.7410	0.4907	1.3244	0.1776	−0.0115					.985	1.78	.29
		(2.98)	(1.84)	(0.87)	(−0.50)							
3	−.0273	.3384	.5949	.1578	.0099	.0009	−.0002	.0014		.985		
		(4.03)	(4.00)	(2.14)	(1.61)	(.30)	(−.05)	(.37)				
4	−.0620	.3535	.5775	.1562	.0110					.984	1.25	.41
		(4.40)	(3.95)	(2.30)	(1.97)							
5	−.0045	.3436	.4808	.2017	.0111					.984		
		(38.85)	(38.85)	(38.85)	(38.85)							
		$PC1$	$PC2$	$PC3$	$PC4$							
6	3.1729	−.1730	−.0486	.2271	−.6914	−.0036	−.0022	.0018	1.683	.988		
		(4.87)	(−.84)	(1.13)	(−2.26)	(−.88)	(−.33)	(−.25)				
7	3.1617	−.1757								.984	1.27	.40
		(38.853)										

[a] Model 1 is pure ordinary least squares (OLS); model 2 is OLS with exact linear restrictions; model 3 is mixed estimation; model 4 is mixed estimation with exact linear restrictions; model 5 is principal components regression (PCR) (model 7 results in terms of the original variables); model 6 is OLS on principal components and dummy variables; and model 7 is 6 with exact linear restrictions.

[b] Values in parentheses are t-values.

are zero was accomplished using an F-test.[2] The test served a dual purpose in this context. The obvious information provided by the test was a statistical decision regarding the significance of the government-planning periods in affecting Thai agricultural output growth.

The second purpose for the test was to assist in selecting a model that would best meet the study objective of obtaining accurate estimates of production elasticities. It is well known that the restricted least squares estimator has a variance-covariance matrix that is smaller than the variance-covariance matrix of the unrestricted least squares estimator by a positive semidefinite matrix for any linear restrictions on the parameters of a linear model (Goldberger). However, if the restrictions are not true, bias is introduced into the estimates of the parameters of the restricted model. The choice between the restricted and unrestricted estimates then involves the classic tradeoff between decreased variance and increased bias (Wallace, pp. 432–33). In practice, the bias and variance characteristics of an estimator are often combined into various mean-square error measures that are used to assess the accuracy of the estimator. The three measures that appear to have received the most attention in the literature and that are used to assess estimator accuracy in this study are the risk matrix criterion

$$(3)\quad MSE(\hat\beta, \beta) = E[(\hat\beta - \beta)(\hat\beta - \beta)'],$$

and the two quadratic risk functions

$$(4)\quad \rho(\hat\beta, \beta) = E[(\hat\beta - \beta)'(\hat\beta - \beta)], \text{ and}$$

$$(5)\quad \rho(X\hat\beta, X\beta) = E[(X\hat\beta - X\beta)'(X\hat\beta - X\beta)] = E[(\hat\beta - \beta)'X'X(\hat\beta - \beta)]$$

(Wallace, pp. 434–38), where X is the $(n \times k)$ matrix of explanatory variable values, and $\hat\beta$ is an estimator of β.

The risk criteria differ in the parameter space over which risk is measured, and a brief digression into the meanings of the risk measurements as they pertain to estimator comparisons will be useful. With reference to the risk matrix criterion (3), an estimator $\hat\beta$ is said to be strong mean square error ($SMSE$) superior to an estimator $\tilde\beta$ iff $MSE(\tilde\beta, \beta)$ exceeds $MSE(\beta, \beta)$ by a positive semidefinite matrix. Superiority of $\hat\beta$ in $SMSE$ thus implies that the mean square error of any linear combination of the entries in $\hat\beta$ is less than or at most equal to the mean square error of the corresponding linear combination of the entries in $\tilde\beta$. Estimator superiority is judged over the parameter space of all possible linear combinations of the entries in β.

[2] The test is calculated as

$$\frac{(C\beta)'[C(X'X)^{-1}C']^{-1}(C\beta)}{gS^2} \sim F(n-k),$$

where g is number of independent constraints to be tested (in this case g equals the number of variables deleted, i.e., the number whose parameters have been constrained to zero), n is number of observations, k is number of parameters estimated, S^2 is the square of the standard error of the equation, and C is appropriately defined.

Using risk function (4), an estimator $\hat{\beta}$ is said to be weak mean square error superior (*WMSE*) to an estimator $\tilde{\beta}$ iff $\rho(\hat{\beta}, \beta) \leq \rho(\tilde{\beta}, \beta)$. This implies that $\hat{\beta}$ is closer, on the average, to β in squared Euclidian distance (Wallace, p. 434). Estimator superiority is judged with specific reference to the entries in the β vector. Note that *SMSE* superiority implies *WMSE* superiority, since if $\hat{\beta}$ is *SMSE* superior to $\tilde{\beta}$

$$(6)\quad \rho(\hat{\beta}, \beta) - \rho(\tilde{\beta}, \beta) = tr\, MSE(\hat{\beta}, \beta) - tr\, MSE(\tilde{\beta}, \beta) \leq 0,$$

where tr is the trace operator. That is, under *SMSE* superiority of $\hat{\beta}$ over $\tilde{\beta}$, $MSE(\hat{\beta}, \beta) - MSE(\tilde{\beta}, \beta)$ will be negative semidefinite, and thus the difference between the traces in (6) will be less than or equal to zero, satisfying the *WMSE* criterion. *WMSE* superiority is necessary, but not sufficient, for *SMSE* superiority.

Using the risk function (5), $X\hat{\beta}$ is superior to $X\tilde{\beta}$ in predicting $E(Y|X) = X\beta$ iff $\rho(X\hat{\beta}, X\beta) \leq \rho(X\tilde{\beta}, X\beta)$. This implies that $X\hat{\beta}$ is closer, on the average, to $E(Y|X) = X\beta$ in squared Euclidean distance. Estimator superiority is judged with reference to the specific linear combinations of the entries in the β vector inherent to $X\beta$. Note that *SMSE* superiority also implies superiority in this predictive sense, since if $C'\hat{\beta}$ has mean square error less than or equal to that of $C'\tilde{\beta}$ for all choices of the real vector **C**, C' can be chosen to be the various rows of the matrix X, and the result on predictive superiority follows. Predictive superiority in terms of (5) is necessary, but not sufficient, for *SMSE* superiority.

If the researcher knew the values of (3), (4), or (5) for two different estimators under consideration, and (3), (4), or (5) were deemed to represent adequately the risks of the estimators, then the estimator exhibiting the lower risk value clearly would be chosen. Of course, in practice, the researcher rarely if ever has knowledge of the values of risk measures (3), (4), or (5). The researcher then has two options with which to proceed. One option is to test the hypothesis that the restricted estimator is *SMSE*-superior, *WMSE*-superior, or superior in the predictive sense to the unrestricted model.

Toro-Vizcarrondo and Wallace have shown that the restricted estimator will be *SMSE*-superior to the conventional least squares estimator when the noncentrality parameter, Θ, of the conventional F-test of the restrictions is less than or equal to .5. Bock, Judge, and Yancey have shown that the restricted estimator is superior in the sense of predictive risk function (5) if the noncentrality parameter of the F-test is less than or equal to $J/2$, where J is the number of independent restrictions tested. Bock, Judge, and Yancey also have exhibited the upper bound for the noncentrality parameter, below which the restricted estimator is superior using the risk function (4); however, the bound depends on the structure of the problem under consideration, and thus a general bound cannot be stated.

The null hypothesis of the test is that the noncentrality parameter is less than or equal to the upper bound for superiority associated with the risk measure chosen. The test is accomplished using the standard F-statistic, and the critical value is generated using the noncentral F distribution with noncentrality equal to the relevant upper bound, and type I error chosen by the researcher. The null hypothesis of superiority is rejected or not at the chosen level of type I error depending on whether the calculated F value exceeds the critical value. Thus, the test in this context provides evidence as to whether an estimator is superior to an alternative estimator based on a specific risk measure.

A second option, which is often followed, is to choose between the restricted and unrestricted estimator based on the outcome of a statistical test of the restrictions. The researcher then is thrust into the pretesting dilemma (Wallace). An intuitively appealing approach to model choice would be to test statistically whether the value of the noncentrality parameter of the F-statistic were greater or less than the appropriate critical upper bound associated with the chosen risk measure, and choose the unrestricted or restricted model accordingly. However, the statistical test of the restrictions is subject to errors whose frequencies, given the number of restrictions and degrees of freedom, are governed by the probability of type I error set for the test. That is, in a repeated sampling context, there will be a nonzero probability of choosing the estimator with the higher risk function value when a pretest is used to choose the final model. Therefore, the pretest estimator, as the final estimator is called, will be a probabilistic mixture of the restricted and unrestricted estimators, and will exhibit variance and bias properties different from either the restricted or unrestricted models. However, a general characteristic of the pretest risk functions

[i.e., (4) and (5)] is that their risk values lie above the minimum of the risk values of the restricted and least squares estimators for all values of noncentrality. This underscores the fact that in a repeated sampling context, the researcher utilizing pretesting for final model choice will never be able to attain the minimum risk that would accrue to an estimator chosen on the basis of a known value of noncentrality (i.e., known degree of validity in the restrictions).

Because the level chosen for the probability of type-*I* error will affect the mixture of the restricted and unrestricted estimators (and hence the properties of the pretest estimator), a question arises as to the optimal level of the type-*I* error to use in a pretest. One method used to choose type-*I* errors, and hence critical test values, and the method used in this study, is the minimax regret approach of Brook. The minimax regret approach chooses the level of type-*I* error so as to minimize simultaneously the maximum positive difference (regret) between the risk functions of the pretest estimator and the restricted estimator, and the maximum positive difference (regret) between the risk functions of the pretest and unrestricted estimator over all potential values of the noncentrality parameter Θ. Thus, in effect, the potentially worst additional risk cost that the researcher faces for not knowing the noncentrality parameter associated with the restrictions is minimized by the minimax regret procedure.

The minimax regret procedure has been developed for risk functions (4) and (5). There is currently no procedure corresponding to risk measure (3). It should be noted that the Brook minimax regret procedure utilizes a diffuse prior on the noncentrality parameter, which implies that the researcher is completely ignorant with regard to the validity of the restrictions. Thus, the minimax critical values tend to be rather conservative, because in most applications restrictions are applied with the presupposition that the restrictions are approximately correct—Θ is small (Wallace, p. 438), and a prior on Θ weighting values of Θ close to zero more heavily will tend to increase a weighted minimax regret critical value.

The specific procedure used in this study to assess the relative accuracies of the restricted and unrestricted estimators, and to decide upon a final estimator, was a hybrid of the two concepts discussed above. An *F*-test of the restrictions was constructed. Then the probability of a noncentral *F* being greater than or equal to the calculated *F*-statistic was determined, where the noncentrality parameter was set equal to the *SMSE* bound of .5. The probability value so determined was used as an indicator of confidence in the null hypothesis of *SMSE* superiority of the restricted estimator, and of course is referred to in the statistics literature as the most impressive confidence level of the test. The probability value associated with the test of restricting all three of the government-planning period dummy variable coefficients to zero was determined to be $P[F(3, 19; .5)] \geq 1.78 = .29$. The results lend a fair amount of support to the hypothesis that the restricted estimator (model 2 in table 2) is *SMSE* superior to the least squares estimator (model 1).

Next, the minimax regret critical value associated with the predictive risk measure (5) was calculated following procedures suggested by Brook (tabled values applicable to the case at hand were not available) and was found to be 1.93. Since the calculated *F*-value was $1.78 < 1.93$, the restricted estimator (model 2) is the final model chosen based on minimax regret for the predictive risk measure. The result was interpreted in its literal context—if the researcher were completely ignorant of the validity of the proposed restrictions and wished to minimize the maximum potential positive difference between the values of the pretest estimator's predictive risk measure and the values of the risk measure of the restricted and least squares estimators over all possible values of noncentrality, the choice would be the restricted estimator.

Finally, the minimax regret critical value associated with the weak mean square error risk measure (4) was calculated following Brook (again, the few tabled values reported by Brook were not applicable) and found to be 1.61 in this case. Thus, based on minimax regret, and the weak mean square error risk measure, maximum regret is minimized by choosing the least squares estimator (model 1).

Therefore, the signals were mixed regarding the relative accuracies of the restricted and least squares estimators. We chose to concentrate on the restricted estimator of the production function because, for reasons discussed earlier, our prior notions suggest that the effects of the government planning periods were near zero, and that the noncentrality asso-

ciated with the three zero restrictions should be more heavily weighted for small values.

It should be noted further that the standard critical central F-value for 3 and 19 degrees of freedom, and level of type I error equal to .05, is 3.13. Thus, the null hypothesis that the government-planning period dummy variables have zero coefficients cannot be rejected at the standard .05 level. Notice that the minimax regret critical value is substantially lower than the standard critical value, which is typical.

Examination of the reduced OLS model (model 2, table 2) reveals that although standard errors of the parameter estimates were generally reduced, the parameter estimates associated with the capital and time variables remain relatively imprecise. The estimated production elasticity for labor of 1.3244, although reduced, still seems unreasonably high on theoretical grounds. In response to the unsatisfactory performance of this exactly restricted OLS estimator in the presence of severe multicollinearity, the alternative estimation techniques of mixed estimation and principal components regression were subsequently examined.

Mixed Estimation

Often the researcher has prior notions concerning the signs and general ranges of magnitudes of at least some of the parameters in his or her model. This prior information emanates from previous research, economic theory, the institutions surrounding the system, and/or introspection by the researcher. In fact, researchers are admitting implicitly to possessing prior information whenever a model is estimated and subsequently rejected due to nonconformity with the researcher's expectations regarding signs and general magnitudes of the parameters.

The mixed-estimation technique originated by Theil and Goldberger is a method of combining a pure model (based on sample information only) with prior information in the form of stochastic linear constraints on the parameters of a general linear model. The most important property of the mixed estimator from the standpoint of the multicollinearity problem is that the potential exists for obtaining estimates that are lower in mean square error measure than estimates using (pure) OLS. Hypothesis tests of the mean square error superiority of mixed estimates based on the noncentral F distribution have been developed (Yancey, Judge, Bock; Judge, Yancey, Bock).

One source of information influencing the authors' prior notions concerning Thai agriculture were the results from previous studies of aggregate agricultural productivities in other countries. Table 3 summarizes the studies surveyed.

Reflecting on previous research and on direct observation of the agricultural sector in Thailand, the following estimates of the ranges and general magnitudes of agricultural output elasticities with respect to land, labor, and capital were decided upon by the authors:

$$(7)\quad \begin{aligned} &E_{Q,LAND} \in [.10, .50] \text{ with probability } .95,\\ &E_{Q,LABOR} \in [.25, .85] \text{ with probability } .95,\\ &E_{Q,CAPITAL} \in [0., .30] \text{ with probability } .95.\end{aligned}$$

The prior point estimates of the elasticities were designated as the midpoints of the intervals in (7), and estimates were assumed to be generated from normal priors with variances .01, .0225, and .005625, respectively, and with zero covariances. The stochastic restrictions are represented as

$$(8)\qquad \mathbf{R}\beta + \mathbf{v} = r,$$

where $\mathbf{R}\beta$ is a (3×1) vector representing the land, labor, and capital elasticities, $\mathbf{v}$ is a (3×1) vector of normally distributed disturbances, and $r' = (.3, .55, .15)$.

The production function (1) was estimated subject to the stochastic constraints on the magnitudes of the output elasticities with respect to land, labor, and capital. The results are presented in model 3 of table 2. Judging by the t-values associated with the parameter es-

Table 3. Relative Importance of Land, Labor, and Capital in Agricultural Output of Selected Countries in Selected Time Periods

		Relative Input Weights		
Area	Years	Land	Labor	Capital
Taiwan[a]	1952–56	.25	.45	.30
Japan[b]	1930–35	.15	.40	.45
Japan[b]	1960–65	.20	.30	.50
Japan[c]	1933–37	.26	.52	.22
India[d]	1947–48	.25	.34	.41
U.S.A.[e]	1949	.19	.33	.48
People's Republic of China[f]	1952–57	.25	.55	.20

Sources: [a] Ho; [b] Akino and Hayami; [c] Tang 1963; [d] Khan; [e] Griliches; [f] Buck; and Tang, n.d.

timates, the coefficients on land, labor, capital, and time appear to have been estimated relatively precisely, while the dummy variable coefficient estimates appear to be much less precise.

In this case, there were two sets of constraints that required examination. The first set of three restrictions, as before, refer to the deletion of the government-planning period dummy variables from the model and are exact linear restrictions. The second set of three constraints refer to the stochastic restrictions on the output elasticities with respect to land, labor, and capital (7) and (8). The alternative estimators of interest here are the mixed estimator with dummy variables deleted (i.e., the restricted model) and the OLS estimator with dummy variables included (the unrestricted model).

In assessing the relative accuracy of the two estimators, a procedure analogous to that used previously was followed. To be specific, the stochastically restricted model was first converted to a generalized equality-restricted estimator following Judge, Yancey, and Bock. Then, as before, an F-statistic was calculated corresponding to the restrictions,[3] which in this case referred to the three exact and three stochastic restrictions, and its value was 1.25 (see Judge, Yancey, and Bock). The probability that a noncentral F-variate with 6 and 19 degrees of freedom and noncentrality equal to .5 is greater than or equal to 1.25 was calculated to be $P[F(6, 19; .5)] \geq 1.25 = .41$. This result provided rather strong support for the hypothesis that the mixed estimator with dummy variables deleted was *SMSE* superior to the ordinary least squares estimator. The minimax regret critical value based on the predictive risk measure was 1.96, and thus the mixed estimator with dummy variables deleted was the choice based on minimax regret for the predictive risk measure. The minimax regret critical value based on the weak mean square error risk measure was 1.22, and thus the least squares estimator was the choice in this last case. It should be noted that the conventional critical central F-value for 6 and 19 degrees of freedom, and level of type I error equal to .05, is 2.63. Thus, the null hypothesis that the government-planning period dummy variables have zero coefficients, and that the sample and stochastic prior information are compatible (Theil) cannot be rejected.

Again, accuracy signals are mixed. We again chose to concentrate on the mixed estimator with dummy variables deleted, because our prior notions suggested that the noncentrality should be more heavily weighted for small values; that is, we felt that the biases in our restrictions, if any, should be low.

For the mixed estimator (model 4, table 2), the share of the posterior precision due to the stochastic prior information (Theil) was calculated to be .48. Therefore, nearly half of the posterior precision of the mixed estimator was due to stochastic prior information, while slightly more than half was due to stochastic sample information.

The mixed estimates (model 4) of the output elasticities with respect to land, labor, and capital were each lower in value than were the corresponding final least square estimates. The most notably different estimates are the estimate of the labor elasticity, which was reduced in magnitude by more than half, and the effect of the time technology proxy, which changed from having a negative to having a positive effect. The estimate of the homogeneity of the production function conditional on time was reduced from 1.9927, estimated via least squares, to 1.0872, estimated via mixed estimation. The coefficients estimated by the mixed model are considered much more reasonable on theoretical grounds than those estimated by the pure OLS or the exact linear restrictions models. Examination of the t-values associated with the mixed coefficient estimates suggest that the precision in estimation has been improved substantially over the least squares approach, mitigating the effects of a rather severe multicollinearity problem.

Principal Components Regression

In the PCR technique, a set of explanatory variables is converted into a set of orthogonal components via an information preserving orthogonal transformation. One or more components are deleted from the analysis by some established criterion (Hill, Fomby, Johnson), and a regression of the dependent variable on the remaining components is performed. Estimates of the parameters associated with the original explanatory variables can be obtained

[3] It should be noted that in the case of mixed estimation, testing results are only asymptotically valid, because the test statistics involve the true variance, σ^2, of the disturbances, μ, in a nontrivial way, for which s^2, a consistent estimate of σ^2, is substituted (see Judge, Yancey, Bock).

by substituting for the components in the regression their equivalent in terms of linear combinations of the explanatory variables (see J. Johnston, pp. 329–30).

The PCR estimates, being restricted estimators, generally will have lower variances than OLS estimates, but they generally will be biased. Under appropriate conditions, the PCR estimator will dominate the OLS estimator in measures of mean square error (Hill, Fomby, Johnson). It is this potential reduction in mean square error that makes the PCR technique attractive for mitigating the effects of multicollinearity.

It was desirable in the PCR analysis to maintain the integrity of the planning-period dummy variables for the hypothesis-testing objectives. Consequently, only a partial PCR procedure was used. Specifically, the natural logarithms of land, labor, and capital, together with the time variable were converted into four orthogonal principal components and a regression of agricultural output on these components and the three dummy variables was performed. The results are displayed in model 6 of table 2.

Upon examining the four principal components ordered according to increasing characteristic roots, it was found that the fourth component accounted for more than 98% of the total variation in the natural logarithms of land, labor, and capital, and in the time variable. Consequently, the deletion of the first three principal components, together with deletion of the planning-period dummy variables from the regression, was contemplated.

The probability of a noncentral F with 6 and 19 degrees of freedom and noncentrality equal to .5 being greater than or equal to 1.27, the calculated F statistic corresponding to the six zero restrictions, was found to be $P(F(6, 19; .5) \geq 1.27) = .40$. This provided significant support for the null hypothesis that the PCR estimator was strong *SMSE* superior to the least squares estimator. The minimax regret critical value for the predictive risk measure was 1.96. Thus, the PCR estimator was the choice based on minimax regret for the predictive risk measure. The minimax regret critical value for the weak mean square error risk measure was 1.45. Thus, the PCR estimator was also the choice based on minimax regret for weak mean square error risk.

In this case, all accuracy measures examined resulted in the PCR estimator being chosen as superior to the least squares estimator. It should again be noted that the null hypothesis of zero coefficients on the dummy variables, as well as zero coefficients on three principal components, cannot be rejected at the standard .05 level of type I error, since the central F critical value for 6 and 19 degrees of freedom equals 2.63.

The final PCR model listed as model 7 in table 2 was one that retained only the principal component with the largest characteristic root, and deleted all other components along with the three planning-period dummy variables. In model 5 of table 2, the fourth principal component was replaced with its equivalent linear combination of $\ln L$, $\ln N$, $\ln K$, and t to derive parameter estimates associated with these variables. The estimates of the land, labor, and capital output elasticities, and especially the coefficient on time observed in model 5, are remarkably similar to those estimated in model 4 via mixed estimation. The principal components estimates in model 5, of course, are based only on sample information. Again, the individual output elasticities and the conditional degree of homogeneity of the production function, equal to 1.0261, appear much more reasonable on theoretical grounds than the estimates generated by models 1 and 2. The estimates using principal components regression appear to be very precise, although it should be noted that due to the retention of only one component, the randomness inherent in the estimates of the land, labor, capital, and time coefficients is one-dimensional. This is reflected by the identical t-values displayed for model 5.

Contribution of Increased Input Use and Technological Progress to Agricultural Output Growth

In order to ascertain the contribution of conventional inputs and neutral technological progess on Thai agricultural output growth, the increase in agricultural output between 1950 and 1976 was decomposed into a movement along the 1950 production surface because of increased use of conventional inputs and an upward shift in the production surface caused by neutral technological progress. Output share estimates and technological progress growth-rate estimates using parameter estimates derived from exactly restricted least squares (model 2), mixed estimation (model 4), and principal components regression (model 5) are displayed in table 4.

Table 4. Shares of Conventional Input Expansion and Technological Progress in Increased Agricultural Output in Thailand, and Growth Rate Due to Technological Advance, 1950–76

Estimating Technique	Input Share	Technology Share	Technology Induced[a] Output Growth Rate
Restricted least squares	1.525	−.525	−.0115 (−.50)
Mixed estimation	.628	.372	.0110 (1.971)
Principal component regression	.624	.376	.0111 (38.853)

[a] The growth rate is given as $(dQ/dt)/Q$, that is, the coefficient of t in the models. The values in parentheses are the t-values associated with the estimated growth rates.

The restricted least squares estimates would indicate that there was technological decay rather than growth. Given the imprecision with which the coefficient on the technology variable was estimated, together with the rather suspect size of the output elasticity with respect to labor, it seems advisable to concentrate on the results provided by mixed estimation and principal component regression. These results are remarkably similar, indicating that the increase in conventional input levels from 1950 to 1976 would account for slightly more than 62% of the agricultural output growth, while technological growth would account for the remainder. Output growth due to neutral technological progress was estimated to be about 1.1% per year by both of these methods.

Summary and Conclusions

The techniques of mixed estimation and of principal components regression (PCR) were each used in an effort to mitigate the effects of a severe multicollinearity problem that was preventing accurate estimation by OLS techniques of an aggregate agricultural production function for Thailand. In addition, pretest considerations of the process of selecting a final specification for each technique utilized were formally addressed.

Both mixed estimation and PCR markedly improved the precision and theoretical reasonableness of estimated parameters on land, labor, capital, and time (a technology proxy). Despite the contrasting conceptual foundations of mixed estimation and PCR, the numerical results were remarkably similar in this application. Both approaches estimated the rate of Thai output growth attributable to neutral technological progress to be about 1.1% per year between 1950 and 1976, whereas a negative rate was estimated by OLS. Both mixed estimation and PCR estimated the degree of homogeneity of the utilized Cobb-Douglas production function to be between 1.0 and 1.1, whereas the comparable OLS estimate was nearly equal to 2.0. The results of mixed estimation and PCR each attributed slightly over one-third of total Thai output growth during 1950–76 to neutral technological progress and the remaining two-thirds to expanded use of land, labor, and capital. None of the estimating techniques employed detected a statistically significant differential impact of economic planning periods on the rate of neutral technological progress in Thai agriculture.

In view of the consistency of these quantitative results, the authors believe the qualitative conclusion that advances in technology played an important role in Thai agriculture during the past three decades cannot be denied. Explanations for this apparent realization of some productivity gains in Thai agriculture, and the apparent neutral impact of the Thai government's economic planning periods, call for a more explicit examination of the Thai agricultural development experience.

While no significant shifts in Thai government agricultural policies (including expenditure rates) were found among the different subplanning periods, the agricultural sector continued to receive a large share of the government's total budget (Tasanasanta, chap. 4; Silcock, p. 186). These Thai government policies and programs may have contributed to the agricultural productivity gains through impacts on crop diversification and improved cultivation practices as well as through some increased provisioning of irrigation water-control facilities. Tasanasanta (chap. 4) shows a significant trend of crop diversification over the period attributed to improved farmer knowledge of nonrice cultivation techniques and seeds, and reinforced by the "rice premium policy" (which artifically lowered the domestic price of rice).

Paralleling crop diversification trends, imports of chemical fertilizers, pesticides and

fungicides increased rather significantly until the mid-1960s, but have increased at much lower rates since then (Tasanasanta). Domestic production of chemical fertilizers and pesticides has been minimal.

Government policies also have helped to improve irrigation, transportation, and extension education in agriculture since 1950. In aggregate terms, there were only 3.8 million irrigated rais in 1947, about 9.8 million rais (or about 14% of total cultivated land) in 1964–66, and 14 million rais (20% of total cultivated land) in 1969 (Tasanasanta, p. 86). Between 1950 and 1976, considerable road construction and railway rehabilitation had been undertaken, while substantial agricultural extension-education programs have been promoted by the government over the same period—including agricultural research at experiment stations throughout the country.

Nevertheless, the quantity and distribution of government infrastructure investment continue to be important factors limiting the acceleration of productivity growth in Thai agriculture. The Thai irrigation system still is far below its potential insofar as the irrigated area accounts for only one-fifth of the cultivated area, and 80% of these irrigated areas are located in the central region. Feeder canals, dikes, and other water distribution facilities have not kept pace with dam construction. The northeast region, where water is scarce, has been waiting for an effective irrigation system. Roadways show a similar pattern with irrigation developments; many connecting roads have not been constructed to permit interregional traffic which would bring large numbers of people into contact with external markets.

Notwithstanding the possible limitations on these interpretative explanations, this paper has demonstrated the potential usefulness of exact and stochastic restrictions in increasing precision of estimated parameters in the presence of extreme multicollinearity. It also formally addressed pretest considerations of the estimators which emerged from the model selection process. The precise estimation of this particular aggregate agricultural production function, and the subsequent analysis of agricultural output growth in Thailand, would not have been feasible had the alternatives to the OLS-estimating technique not been available.

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References

Akino, Masakutsu, and Yujiro Hayami. "Sources of Agricultural Growth in Japan, 1880–1965." *Quart. J. Econ.* 88(1974):454–70.

Bock, M. E., G. Judge, and T. A. Yancey. "The Statistical Consequences of the Preliminary Test Estimators in Regression." *J. Amer. Statist. Assoc.* 68(1973):109–16.

Brook, Richard J. "On the Use of a Regret Function to Set Significance Points in Prior Tests of Estimation." *J. Amer. Statist. Assoc.* 71(1976):126–31.

Brown, Murray. *On the Theory and Measurement of Technological Change*. London: Cambridge University Press, 1966.

Brown, William. *Effect of Omitting Relevant Variables Versus Use of Ridge Regression in Economic Research*. Oregon Agr. Exp. Sta. Spec. Rep. No. 394, Corvallis, Oct., 1973.

Brown, William, and Bruce R. Beattie. "Improving Estimates of Economic Parameters by Use of Ridge Regression with Production Function Applications." *Amer. J. Agr. Econ.* 57(1975):21–32.

Buck, J. L. *Chinese Farm Economy*, pp. 86–87. Chicago: University of Chicago Press, 1930.

Cobb, Charles W., and Paul W. Douglas. "A Theory of Production." *Amer. Econ. Rev.*, supplement, 18(1928):139–56.

Goldberger, A. S. *Econometric Theory*. New York: John Wiley & Sons, 1964.

Griffen, Keith. *The Political Economy of Agrarian Change: An Essay on the Green Revolution*. Cambridge, Mass.: Harvard University Press, 1974.

Griliches, Zvi. "Sources of Measured Productivity Growth." *J. Polit. Econ.* 71(1963):331–46.

Hill, R. C., and Thomas B. Fomby. "Deletion Criteria for Principal Components Regression Analysis." *Amer. J. Agr. Econ.* 60(1978):524–27.

Hill, R. C., Thomas B. Fomby, and S. R. Johnson. "Component Selection Norms for Principal Components Regression." *Commun. Statist.* A6(1977): 309–34.

Ho, Yhi-min. *Agricultural Development of Taiwan, 1903–1960*. Nashville, Tenn.: Vanderbilt University Press, 1966.

Hoerl, A. E., and R. W. Kennard. "Ridge Regression: Biased Estimation for Nonorthogonal Problems." *Technometrics* 12(1970):55–67.

Holloway, M. "A Production Function Analysis of Water Resource Productivity in Pacific Northwest Agriculture." Ph.D. thesis, Oregon State University, 1972.

Hsieh, S. C., and V. W. Ruttan. "Environmental, Technological, and Institutional Factors in the Growth of Rice Production: Philippines, Thailand, and Taiwan." *Food Res. Inst. Stud.* 7(1967):307–41.

Johnston, Bruce F. "Agriculture and Structural Transformation in Developing Countries: A Survey of Research." *J. Econ. Lit.* 8(1970):369–404.

Johnston, J. *Econometric Methods*. New York: McGraw-Hill Book Co., 1972.

Judge, G. G., T. A. Yancey, and M. E. Bock. "Properties of Estimators after Preliminary Tests of Significance

When Stochastic Restrictions Are Used in Regression." *J. Econometrics* 1(1973):29–48.

Khan, N. A. *Problems of Growth of an Underdeveloped Economy*. Bombay, India: Asia Publishing, 1961.

Moscardi, E., and A. de Janvry. "Attitudes toward Risk among Peasants: An Econometric Approach." *Amer. J. Agr. Econ.* 59(1977):710–16.

Ministry of Agriculture and Cooperatives. *Agricultural Statistics of Thailand*. Bangkok, 1975–76.

Mittelhammer, Ron, and John Baritelle. "On Two Strategies for Choosing Principal Components in Regression Analysis." *Amer. J. Agr. Econ.* 59(1977):336–43.

Mittelhammer, Ron, and David Price. "Estimating the Effects of Volume, Price, and Costs on Marketing Margins of Selected Fresh Vegetables through Mixed Estimation." *Agr. Econ. Res.* 30(1978):1–7.

Myint, H. *Southeast Asia's Economy: Development Policies in the 1970s*. New York: Praeger Publishers, 1972.

Nevel, Robert O. "Technological Change in Agriculture." *Agr. Econ. Res.* 21(1969):13–18.

Price, David W., and Ronald C. Mittelhammer. "A Matrix of Demand Elasticities for Fresh Fruit." *West. J. Agr. Econ.* 4(1979):69–86.

Silcock, T. H. *The Economic Development of Thai Agriculture*. Ithaca, N.Y.: Cornell University Press, 1970.

Solow, Robert M. "Technical Change and the Aggregate Production Function." *Rev. Econ. and Statist.* 39 (1957):312–20.

Sriplung, S. *Poverty of Farmers and Solutions*. Bangkok, Thailand: Rusm Mitra Thai Publishers, 1976 (Thai version).

Tang, A. M. "Research and Education in Japanese Agricultural Development, 1880–1938." *Econ. Stud. Quart.* 13(1963):27–41 and 91–99.

Tang, A. M. *Input-Output Relations in Agricultural Output of Communist China, 1952–65*. Mimeographed. Vanderbilt University, no date.

Tasanasanta, Damrongsak. "Sources of Agricultural Growth in Thailand, 1950–1976." Ph.D. thesis, Washington State University, 1978.

Theil, H. "On the Use of Incomplete Prior Information in Regression Analysis." *J. Amer. Statist. Assoc.* 58 (1963):401–14.

Theil, H., and A. S. Goldberger. "On Pure and Mixed Statistical Estimation in Economics." *Int. Econ. Rev.* 2(1961):65–78.

Toro-Vizcarrondo, C., and T. D. Wallace. "A Test of the Mean Square Error Criterion for Restrictions in Linear Regression." *J. Amer. Statist. Assoc.* 63 (1968):558–72.

Wallace, T. D. "Pretest Estimation in Regression: A Survey." *Amer. J. Agr. Econ.* 59(1977):431–43.

Yancey, T. A., G. G. Judge, and M. E. Bock. "A Mean Square Error Test When Stochastic Restrictions Are Used in Regression." *Comm. in Statist.* 3(1974): 755–68.

Zellner, A. *An Introduction to Bayesian Inference in Econometrics*. New York: John Wiley & Sons, 1971.

Notes

Benefits, Costs, and Distributional Consequences of a Publicly Assisted Marketing Cooperative

John Hoehn, Lynn W. Robbins, and Kurt R. Anschel

During the last two decades, public policy makers have recognized a need to enhance the earning capacity of low income rural residents. For the rural population now supplementing minimal incomes with income from agricultural production, current policy instruments are slow in effect. Designed primarily for long-run development of nonagricultural employment through industrialization and the enhancement of human capital through schooling, such policies largely ignore small farms as a transitional source of income and employment. An exception to this general tendency, Title III of the Economic Opportunity Act of 1964 planned to strengthen the income earning capacity of small farm households.

Although larger farms have been served by organizing cooperatively, small, low income farms have appeared limited in their ability to organize cooperatively by inadequate investment capital. Title III sought to ease this perceived capital constraint with a program of grants and loans. The primary objectives were (*a*) to provide the opportunity for increased farm income through productive employment and (*b*) to direct this income enhancement opportunity toward otherwise low income households (U.S. Congress). Existing evaluations tend to stress more the need for changes in administrative procedures than careful consideration of project benefits and costs. Where income changes have been estimated, analytic methods are unclear and leave the significance and validity of such results in doubt. The role of Title III in enhancing the earning capacity of low income rural households has yet to be measured and analyzed. This paper presents a case study that does define Title III's role in affecting rural incomes.

Research Design

The benefits or injury which cooperative organization may offer a community of low income farm households is evaluated through a case study of a southeastern Kentucky marketing cooperative. To parallel the objectives of Title III, the study attempts (*a*) to estimate the magnitude of income benefits accruing to the members and to society as a result of public investment in the cooperative and (*b*) to determine resulting income distributional consequences among cooperative members.

The study cooperative was organized in 1969 and funded without member equity through a Farmers' Home Administration (FmHA) loan and an Office of Economic Opportunity grant. To ensure adequate operating capital, grant disbursal was planned over an eleven-year period. With grant disbursements diminishing each year, member dues and marketing charges progressively assume a larger share of operating capital. The cooperative has yet to generate savings. Assembly and marketing services are performed for a membership that has varied from 300 to 500 producers. Tomatoes, cabbage, and green peppers are sold to fresh markets while growers also may contract for sales of red peppers to processing markets. Cooperative sales have ranged from \$416,000 to \$572,000 in recent years.

Because the output of the cooperative represents only a small increment in market supply, no measurable net change in consumer benefits can be expected. Any change in private or social benefits accrues to those engaged in the production of crops or to those seasonally employed in cooperative processing. The concept of benefits is based on the notion of opportunity cost. Opportunity cost consists of the income attainable had equivalent resources been employed in the next best alternative. Member benefits may be represented as

$$MB_{ik} = \sum_j (R_{ijk} - U_{ijk} - OC_{ijk}),$$

Where MB_{ik} is net benefit received by kth member in ith year; R_{ijk}, the revenue received by kth member in the ith year through sale to the cooperative of output from the jth vegetable enterprise; U_{ijk}, the cash production costs for the ith year and jth enterprise; and OC_{ijk}, the opportunity costs due to income foregone in the ith year by not employing resources of the jth crop in the next best income-producing alternative. Net social benefits derived from the production of the kth member's crop, PB_{ik}, are member benefits plus the wage bill paid to hired labor, less the opportunity costs of hired labor. For labor seasonally employed in the processing and packing of cooperative output, a similar model may be constructed where LB_{il} is the net benefit to the lth worker in the ith year, R_{il} is the

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income received in wages and OC_{it} is the income foregone in the next best alternative employment opportunity.

Social costs incurred through public investment in the cooperative arise over time from both grants and loans. While the full dollar value of the grant is a relevant social cost, the social cost of the loan is the difference between annual repayments made on the loan at the lending rate of interest and the return foregone had the loan been otherwise invested. For a given year, public sector costs are calculated as

$$C_i = G_i + (Ap_i - Ar_i),$$

where C_i is public sector costs in the ith year; G_i, the grants made to the cooperative in the ith year; Ap_i, the foregone annual repayment in the ith year had the loan principal been invested at some discount rate p; and Ar_i, the annual repayment in the ith year on loan principal at the 4⅛% interest rate established by FmHA.

The above measures of benefits and costs lead to a comparison of the real social gain or loss brought about by investment relative to the cost of investment. As a ratio of benefits to investment costs, the analysis discloses the average efficiency of investment. The model is

$$\frac{B}{C} = \frac{\sum_i (1 + p)^{-i} \left[\sum_k PB_{ik} + \sum_t LB_{it} \right]}{\sum (1 + p)^{-i} C_i},$$

where B is present value of project benefits; C, the present value of project investment costs; and p, the socially relevant discount rate. The time horizon, i, can be established by reference to the repayment schedule of the cooperative's FmHA loan. The thirty-year mortgage implies that public sector costs were anticipated over a thirty-year period beginning in January 1969. The value of i, therefore, ranges over the integer values from zero to thirty.[1] Because both benefits and costs occur over time, a discount rate is necessary to ensure that benefits and costs are commensurable. Two discount rates are enlisted in this study. The first calculation is at 5% to reflect the average return on U.S. Treasury securities in the late 1960s, the period when investment in the cooperative was initiated. A second calculation is at 10% and corresponds to the Office of Management and Budget discount rate of the 1970s (Sassone and Schaffer).

Estimating Benefits

Three data sources were critical to the analysis. First, annual grower-contract summaries kept by the cooperative identified individual growers, listed acreages planned by members, and detailed the sales revenues of each grower. Second, to estimate production costs, opportunity costs, and household income, a sample of 160 cooperative members was randomly selected from among 433 participants who had indicated a willingness to produce a crop in 1977. Of the 160 members sampled, 137 respondents completed usable interview schedules. The survey schedule detailed members' experiences with the cooperative and with vegetable crops, the growers' tenure with respect to the acreage planted, household composition, off-farm employment and income, production practices and output from crop and livestock enterprises, and, finally, the growers' income earning alternatives to the production of crops for sale to the cooperative. When respondents were unable to identify an income-producing alternative, opportunity costs were later priced at zero. Third, the revenue and cost-budgeting process was completed by reference to standard budgets (Allen et al.). Data from these budgets became important where collection through the survey would have been impractical.[2]

Social and member benefits derived from production are estimated by combining the cross-sectional results of the survey with the yearly revenue and planned acreage data available from cooperatives records for each member. Considering costs as a function of planned acreage, social benefits from production for 1971 through 1978 are estimated as

$$PB_i = \sum_j \sum_k R_{ijk} - \sum_j \left[\frac{\sum_r C_{rj}}{a + \sum_r A_{rj}} \left(\sum_k AP_{ijk} \right) \right],$$

where PB_i is total benefits from crop production in the ith year; R_{ijk}, revenue received by the kth producer in the ith year for sale of the jth crop; A_{rj}, acreage planned by rth respondent in production of the jth crop in 1977; AP_{ijk}, acreage planned by the kth member for production of jth crop in the ith year; C_{rj}, production costs, including relevant opportunity costs, for the jth vegetable crop grown by the rth respondent; a, sum of acreage planned by those in sample who did not actually grow a crop in 1977; and i, 3, . . . , 10 and corresponds to the years 1971 to 1978. To reflect the difference in private member benefits, MB_{ik}, and social benefits, PB_{ik}, derived from production, C_{rj}, is adjusted. Where private benefits to member households are of concern, C_{rj} includes the full wage bill of any hired labor. When estimating social benefits, C_{rj} includes only the opportunity cost of hired labor. Where hired labor was employed throughout the production season, opportunity costs for hired labor are

[1] To adjust nominal values for changes in the purchasing power of the dollar, all terms are transformed to 1977 constant dollar values by use of the consumer price index. The same adjustment procedure will be used throughout this study where nominal values originate in different time periods.

[2] For example, detailing overhead and machinery costs for each respondent would have carried interviews beyond the practical limit of thirty to forty minutes. Even without some practical limit to interview length, different respondent accounting methods for such costs might well have led to incommensurable results.

valued at the respondent's average per hour opportunity wage. If hired labor was employed only briefly, at harvest, for example, it is assumed that hired labor otherwise would be unemployed and therefore is valued at zero opportunity cost.

For 1969 and 1970, no data are available from the cooperative regarding acreage planned or revenue received by the members. Lacking a more adequate procedure, benefits derived by the membership in 1969 and 1970 are assumed to be equal to their 1971 level.

Benefit-cost analysis commonly requires that a benefit stream be projected into the future. As the time horizon increases, so too does uncertainty regarding the projected benefit stream. Two factors influencing future member benefits are technological innovation and changes in the members' income earning alternatives. Neither of these factors is subject to rigorous probabilistic definition.

In this study, the future benefit stream derived from the services of the cooperative is projected on the basis of the past. Annual future benefits are based upon average annual benefits achieved by the total membership in the period from 1971 to 1978. Average annual benefits are estimated because no discernible trends exist for either sales, membership, or sales per member. Total cooperative sales increased through 1974, declined until 1977 and then increased slightly in 1978. Membership increased through 1974 and since has declined somewhat each year. Gross revenues per member increased through 1974, declined through 1976, and increased in 1977 and 1978.

To account for the uncertainty regarding the permanence of the production-benefit stream, benefit-cost ratios are separately computed under two different assumptions. First, benefits from production are assumed to remain constant and equal to the annual average benefits achieved from 1971 to 1978. Second, the future benefit stream from production is assumed to decline from 1979 onward at a rate of 7% per year. This second assumption is intended to account for (*a*) the possibility of generally rising opportunity costs to labor and concomitant decline in the stock of involuntarily unemployed labor, and (*b*) the possible effects of technological innovation. The choice of a 7% rate is somewhat arbitrary but implies that benefits, measured in constant 1977 dollars, will be approximately halved over each ten-year period.

For labor seasonally employed in the processing and packing of cooperative output, no sampling data is available to estimate alternative employment opportunities. Without adequate sampling data, a portion of the wage bill paid to these temporary workers is included in the benefit-cost analysis under two different assumptions. First, opportunity costs for these workers are assumed to equal zero in the cooperative's first year and to increase on a straight line basis to 80% of the wage bill in the thirtieth year. Wages paid in years eleven to thirty equal the average wage bill of the cooperative in the years 1969 to 1978. Second, to test the sensitivity of the benefit-cost results to the inclusion of seasonal employment benefits, additional ratios are calculated with opportunity costs equal to 100% of the wage bill in all years. This second assumption excludes entirely the possibility of incremental benefits accruing to those seasonally employed at the cooperative.

Benefit-Cost Results

Present value estimates for both benefit and cost streams permit a comparison of the net social gain brought about by public investment in the cooperative relative to the social costs. Depending upon the assumptions adopted and the discount rate selected, socially relevant present values for benefit streams range from $329,017 to $826,092 (table 1).

Given the certainty of public investment by both size and type, social costs vary only with the discount rate and range from $660,979 under the 10% rate to $686,866 under the 5% discount rate (table

Table 1. Present Values of Benefit Streams in Year "0" by Assumption and Discount Rate

	Total Benefit Streams by:			
Discount Rate	Assumptions 1 and 3	Assumptions 1 and 4	Assumptions 2 and 3	Assumptions 2 and 4
	$			
5%	826,292.45	635,305.94	693,922.19	503,135.68
	(591,593.19)[a]	(591,593.19)	(309,783.61)	(309,783.61)
10%	464.044.25	377,407.76	415,653.10	329.016.61
	(233,341.27)	(233,341.27)	(203,388.55)	(203,385.55)

Assumption 1: Benefits from crop production remain constant from 1979 onward at 1971 to 1978 average.
Assumption 2: Benefits from crop production decline at 7% per year from their 1971 to 1978 average beginning in 1979.
Assumption 3: Opportunity costs for seasonally employed rise from zero to 80% of the wage bill over the thirty-year period.
Assumption 4: Opportunity costs for seasonally employed equal 100% of the wage bill in all years.

[a] Parentheses indicate private benefits to members.

Table 2. Present Values of Public Sector Project Costs at Stated Discount Rates

Source of Cost	Present Values in Year t_0 at Discount Rate 5%	10%
	-------- $	--------
Interest subsidy[a]	17,016.41	107,672.97
Grant monies[b]	669,849.58	553,305.95
Total public sector cost	686,865.99	660,978.92

[a] The accounting model is $\sum_t (Ap_t - Ar_t)/(1 + p)^t$.

[b] The accounting model is $\sum_t G_t/(1 + p)^t$.

2). Examining the social cost components, the 10% rate weights more heavily the cost of subsidized interest rate while the 5% rate places more emphasis on the cost of the grants made to the cooperative.

Estimated benefit-cost ratios relevant to public investment range from 0.50 to 1.20, depending upon the assumptions adopted and the discount rate selected (table 3). The ratios imply that, on the average, the return from diverting funds to the cooperative ranges from $0.50 to $1.20 for every dollar invested.

A weakness inherent in benefit-cost analysis results from uncertainty in projecting benefit streams. To deal with uncertainty in benefit projection the four assumptions discussed previously were utilized. Of the assumptions, the second and third assumptions appear to provide the most reasonable projection of benefits and thus result in more reliable benefit-cost ratios. Greatest uncertainty stems from estimating benefits to seasonally employed labor. Over the thirty-year period, these benefits could range from zero to the total value of the

Table 3. Estimated Benefit-Cost Ratios under Differing Assumptions and Discount Rates

	Assumption 1 Discount Rate		Assumption 2 Discount Rate	
	5%	10%	5%	10%
Assumption 3	1.203	0.775	1.010	0.702
Assumption 4	0.925	0.571	0.733	0.498
Private benefits to membership	0.570	0.353	0.451	0.308

Assumption 1: Benefits from crop production constant from 1979 onward at 1971 to 1978 average.
Assumption 2: Benefits from crop production decline at 7% per year from 1971 to 1978 average beginning in 1979.
Assumption 3: Opportunity costs for seasonally employed rise from zero to 80% of the wage bill over the thirty-year period.
Assumption 4: Opportunity costs for seasonally employed equal 100% of wage bill in all years.

wages paid to employees. The assumption that opportunity costs for seasonally employed labor would increase from zero to 80% of the wage bill over the thirty-year period was analyzed as a compromise estimate for this uncertain benefit stream. Again the assumption that opportunity costs for seasonally employed labor would equal 100% of the wage bill in all years was included to weigh the sensitivity of the overall benefit stream to this benefit component.

The direction of change for benefits derived from crop production is more certain. Opportunity costs are likely to increase and thus reduce future benefits from production. Opportunity costs will tend to rise as alternative employment opportunities develop and as local labor gains the skills and knowledge necessary for employment in nonagricultural alternatives. Given these observations, the preferred assumption is that benefits derived from production are approximately halved every ten years after 1978. Employing the two preferred assumptions, the benefit cost ratio is 1.01 at the 5% discount rate and 0.70 at the 10% discount rate.

The desirability of public investment in the cooperative depends upon the discount rate selected, a decision maker's assumptions, and an investment decision criterion. If discount rates properly reflect the investment opportunity costs and if the income distributional objectives may be accomplished through a tax transfer system, the decision not to invest would appear appropriate when the benefit-cost ratio is less than one. With this criterion and a discount rate of 10%, society would be better off by not investing in the cooperative as all benefit-cost ratios are less than one. However, the 5% rate was suggested as the relevant discount rate of the 1960s, the period when investment decisions were actually made. Discounting at 5% and allowing for social benefits to the seasonally employed, estimated benefit-cost ratios indicate the possibility of a small social gain from the cooperative.

Member benefits derived from production are shown in relation to public costs of investment to test for the likelihood of investment in the cooperative by the membership alone. Assuming private investment would occur on the same scale as public investment, the autonomous initiation of the cooperative appears unlikely. Under each assumption and both discount rates, investment cost is at least 43% greater than estimated private benefits.

Income Distributional Effects

A primary objective of public investment in cooperatives is enhanced income-earning opportunities for low income members. The benefit-cost analysis measures allocative efficiency but does not address distributional effectiveness. Where public investment projects have primarily distributional objectives, Weisbrod suggests the concept of target efficiency.

The target efficiency criterion is applied in two directions. The first direction, vertical, addresses the project's ability to apportion benefits toward the intended beneficiary group. This vertical measure discloses (*a*) whether an intended group benefits, and (*b*), if this group does indeed benefit, the proportion of project benefits shared by the group. Vertical efficiency may be measured by the proportion of project benefits shared by the intended beneficiaries. The second direction of target efficiency, horizontal, evaluates the adequacy of benefits received by individuals of the intended beneficiary group (Weisbrod). In practice, horizontal efficiency may be measured by comparing the benefits received by the intended beneficiaries relative to a benefit share considered adequate according to an income standard (Infanger).

To apply the concept of target efficiency in the present analysis, four points must be clarified. First, the intended beneficiaries must be identified. Second, a measure of income must be defined. Third, a minimum income standard must be chosen. Fourth, income levels in the absence of ("without") the cooperative's services need be computed.

The intended beneficiaries of cooperative services are clearly those members who, without the opportunity presented by the cooperative, would be classified as low-income (National Archives, p. 524). By reference to Bureau of the Census guidelines both a measure of income and a standard of income adequacy may be defined. The Bureau of the Census defines income as yearly household receipts from either farm or nonfarm employment less business and farm expenses plus public assistance money payments before deductions for federal and state income taxes (U.S. Bureau of the Census, pp. 193–94). Based on the survey data, income "with" and "without" the services of the cooperative is computed for 1977. The "with" measure of income combines income from all sources, including net income derived from sales to the cooperative. The "without" measure excludes income derived from sales to the cooperative and includes income attainable from the foregone earning activity. To arrive at the relative adequacy of household income both "with" and "without" the services of the cooperative, the standard employed is the matrix of poverty threshold levels published yearly by the Census Bureau. This federal standard adjusts minimum household income requirements for variation in the age and sex of the head of the household, for the number of persons in the household, and for changes in the Consumer Price Index (Bureau of the Census, pp. 195–204).

Vertical Income Distribution

By ranking respondents on "without" income alone and partitioning the resulting "without" income array into quintiles, the vertical efficiency measure is achieved. In table 4, respondent households are grouped into quintiles by their "without" income. All quintiles experience some cash income gain as a result of sales to the cooperative. While the middle income quintiles (2nd, 3rd, and 4th) share in only 19.58% of the cash income gain, the share of the lowest and highest income quintiles (1st and 5th) totals 80.42%. Shares of opportunity costs appear to be almost the inverse of shares of cash income gains. When opportunity costs are subtracted from the cash income gain, the results are striking. The middle income quintiles not only experience a relative decline in income shares, but also incur real income losses. If income maximization is their goal, middle income quintiles would appear to be better off by not participating in the cooperative. While the highest income quintile achieves a gain equal to 76.73% of total respondent benefits, the benefit share of the lowest income quintile is 272.73%.

The effect of these benefit shares on respondent incomes is shown in table 5 where respondents are ranked and arrayed in quintiles by income "without" the cooperative. Results show that there is a slight tendency for total income shares to shift toward lower income quintiles. Perhaps most noticeable is the small effect of benefits, positive or negative, on the total incomes of the four upper quintiles. The second quintile sustains the greatest loss at −2.03% while the fifth quintile experiences a gain

Table 4. Distribution of Benefit Components among Respondents by Income Quintile

		Percentage of Total Benefit Component by Income Quintile[a]				
Benefit Component	Respondent	1st	2nd	3rd	4th	5th
	--- $ ---					
Income derived from crop production for the cooperative[b]	37,164.55	53.45	3.60	12.33	3.65	26.97
Opportunity costs incurred	31,453.65	13.64	18.13	25.41	24.90	17.92
Benefits received	5,710.90	272.73	−76.41	−59.72	−113.33	76.73

Note: Household income measures include allowance for changes in monetary public assistance and transfer payments.
[a] Quintile based upon "without" situation respondent income.
[b] Income derived from crop production is revenue minus cash and overhead costs.

Table 5. Changes in Respondent Income Shares within Quintiles Ranked by "without" Cooperative Generated Household Income[a]

	Quintiles Based on Ranking by "without" Situation Household Income				
	$				
	0–5,372	5,372–8,886	8,886–13,391	13,391–19,385	19,385–42,200
Under "without" situation mean quintile income ($)	3,170.38	7,312.19	10,869.46	15,879.13	25,410.27
Under "with" situation mean quintile income ($)	3,744.49	7,163.65	10,747.65	15,639.41	25,566.79
Percentage change in mean and total quintile income (%)	18.11	−2.03	−1.12	−1.51	0.62

[a] Household income measures include allowance for change in monetary public assistance and transfer payments.

of less than 1%. For the lowest income quintile, benefits derived from the services of the cooperative lead to a substantial increase in quintile income; quintile income increases 18.11% from the "without" situation to the "with."

Horizontal Income Distribution

Horizontal target efficiency measures the adequacy of income increases achieved by low income participants when compared to an income standard. For the households whose incomes fall below the relevant Census Bureau poverty threshold, the household income deficit represents the additional income required to equalize household income with the poverty threshold.[3] The total income deficit is simply the arithmetic sum of individual household income deficits. Because poverty levels remain a relative concept, total income deficits also are estimated for multiples of the relevant poverty thresholds. For a multiple of the poverty threshold, say 0.75, the household income deficit represents the additional income required to equalize household income with 0.75 of the relevant poverty threshold.

[3] This concept is commonly employed by the U.S. Bureau of the Census. See Bureau of the Census.

Results are presented in table 6 and allow a comparison of total income deficits under respective "with" and "without" situations. Total income deficits show a consistent decline across all poverty threshold classes. While tending to diminish in significance as poverty levels rise, the deficit change is greatest for those whose incomes fall below 100% of the poverty level.

Conclusions and Implications

Sizable benefits accrue to low income participants due to services provided by the cooperative. Reducing the net benefit sum, however, are losses experienced by middle income participants. As a whole, benefits accruing to the membership provide insufficient incentive for cooperative formation through private investment alone. Thus, without public investment, social benefits and benefits to the low income members may be lost. In the case of the study cooperative, social benefits do appear to have justified the social costs of public investment at the time investment decisions were made. However, the current 10% Office of Management and Budget discount rate leaves the desirability of simi-

Table 6. Income Deficits of Low Income Respondent Households

Poverty Ratio Classes[a] (Inclusive)	Income Deficit Total "without"	Income Deficit Total "with"	Percentage Change in Income Deficit[b] from "with" to "without"
0.0–0.75	25,396.96	23,031.56	− 9.3
0.0–1.00	53,779.46	48,176.61	−10.4
0.0–1.25	92,623.32	84,661.65	− 8.6
0.0–1.50	146,611.75	136,585.19	− 6.8

Note: Income includes allowance for changes in monetary public assistance and transfer payments.

[a] Poverty ratio is respondent household income divided by the federal poverty threshold relevant to the characteristics of the household in question. See Congressional Budget Office, 1977.

[b] Total income deficit is the additional income required to bring all respondents within the poverty ratio class to the upper bound of the poverty ratio class.

lar present day investment in doubt.[4] Despite these somewhat contrary findings, important conclusions result regarding cooperative organization as a means of enhancing low rural incomes.

First, benefit streams depend on cash income derived from either employment or production and opportunity costs. Though apparent on theoretical grounds, this assertion often is overlooked in project planning and analysis. Because opportunity costs vary between individuals, neither a global endorsement nor a global rejection of low income cooperatives is reasonable. The ability to determine probable benefits and beneficiaries a priori is essential if a goal of public investment for low income cooperatives is social benefits at least equal to social costs. To estimate member benefit levels, prior analysis need consider prospective cash income gains and participant employment alternatives. Both social and private benefits will be greatest, *ceteris paribus*, where low opportunity costs to labor permit labor intensive crop production.

Second, the present analysis has been unable to explore fully the cost side of the benefit-cost ratio. Only actual investment has been considered. With the study cooperative, both public investment and project size appear to have been determined more by agency compromise than a careful consideration of the sales and grower-processing requirements. If both investment and project size had received more adequate planning, benefit-cost ratios likely would be more favorable. The critical question is, "What is the least-cost combination of cooperative services for a given level of benefits?" With this question answered, a combination of loans and grants may be determined which will minimize social costs without unnecessarily jeopardizing the cooperative's financial stability.

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[4] Some may challenge the 10% discount rate as too high. For instance, recent estimates by Boskin result in a discount rate range from 5.6% to 8.9%. However, general policy conclusions are not dependent upon resolving whether the benefit-cost ratio for this particular project is slightly greater or slightly less than one.

References

Allen, Stephen Q., Wilmer Browning, Charles L. Moore, and David L. Debertin. "Estimated Cost and Returns for Production of Various Crops and Livestock in Kentucky during 1977." Agr. Econ. Ext. Info. Ser. No. 16, University of Kentucky, 1977.

Boskin, Michael J. "Taxation, Saving, and the Rate of Interest." *J. Polit. Econ.* 86(1978):523–527.

Infanger, Craig L. "Distributional Effects of Water Projects: An Empirical Example from the Columbia Basin Project." Mimeographed. Prepared for the Symposium on Distribution Effects of National Resource Policy, AAEA meetings, San Diego, Calif., 31 Jul.-3 Aug. 1977.

National Archives and Records Service, Office of Federal Register. *United States Statutes at Large, 1964*, vol. 78, Public Law No. 88-452. Washington, D.C., 1964.

Sassone, Peter G., and William A. Schaffer. *Cost-Benefit Analysis*. San Francisco, Calif.: Academic Press, 1978.

U.S. Bureau of the Census, Department of Commerce. "Characteristics of the Population below Poverty Level: 1975." *Current Population Reports, Consumer Income*, Series P-60, No. 106. Washington, D.C., 1977.

U.S. Congress, House of Representatives, Committee on Education and Labor. "Economic Opportunity Act of 1964, Report No. 1458." 88th Cong., 2nd Sess. 1964.

Weisbrod, Burton A. "Collective Action and the Distribution of Income: A Conceptual Approach." *The Analysis and Evaluation of Public Expenditures: The PPB System*. Washington, D.C.: 91st U.S. Cong., 1st Sess., Joint Economic Committee, 1969.

An Evaluation of Cooperative Extension Small Farm Programs in the Southern United States

David Orden and Steven T. Buccola

During the past decade, new cooperative extension service programs have been developed for the purpose of aiding small and limited resource farmers. Programs have been implemented primarily in the South, a region in which the 1890 land grant institutions focus attention on disadvantaged minorities and in which small farms remain relatively concentrated. Long-term program goals are to expand educational assistance to individuals not reached by other extension programs, to raise small farm productivity, to increase farm sales revenues, and to improve family living standards. Farmers generally participate for a period of two to four years.

Early pilot programs in Texas (1968) and Missouri (1971) involved the experimental use of paraprofessional field staff, themselves selected small farm operators, who worked with their peers on a one-to-one or "neighbor-to-neighbor" basis (Strickland and Soliman; Wiggins). In 1968, the Alabama Cooperative Extension Service directed its professional agricultural agents to allocate part of their time to similar small farm activities (Maddox, Jones, McDaniel). The success of these efforts reinforced the concepts of developing some extension programs specifically for small farm operators, and of employing paraprofessionals to perform such work. Additional federal funds became available in the mid-1970s and programs were initiated in other states. By 1978, small farm programs in the southern region employed more than 250 full-time field workers, primarily paraprofessionals. Annual program expenditures exceeded $2.2 million.

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Research Objectives

This paper presents partial results of an inventory and evaluation of cooperative extension service programs directed at small farm operators in the southern United States (Orden, Buccola, Edwards). Although several states had summarized or assessed their own small farm efforts prior to this study, no comprehensive regional inventory of resources, or evaluation of program strategies or effectiveness, had been undertaken (Atkinson; Enlow, George, Holik, Wiggins; McAfee; Strickland and Soliman; West, Harrold, Schneeberger, Williamson). Similarly, while several recent studies have examined opportunities for increasing incomes derived from small farms, these studies have provided no evidence that extension assistance programs can induce such increases. For example, Stewart, Hall, and Smith, comparing realized with potential incomes on limited resource farms in eastern Kentucky, concluded (p. 81) that "the potential for increasing income exists," but that "the possibility of achieving this potential needs to be explored in greater depth."

In this light, two purposes of the present study were to identify and describe southern cooperative extension small farm programs, and to evaluate the impact of selected program and nonprogram characteristics on achievement of a crucial program goal: increases in farm sales revenue. Findings provide information relevant to defining program audiences and objectives, estimating expected program outcomes, identifying characteristics of effective programs, and determining the extent to which further commitment of resources to small farm programs appears justified.

Data Sources and Initial Inventory

Twenty-three programs in which field staff provide intensive assistance to individual small farm operators were included in the study. Data were provided by personal interviews with forty-three administrators and state specialists at both 1862 and 1890 land-grant institutions and by survey questionnaires completed by local program supervisors and field staff. One hundred-eighty-seven field workers (thirty-five professional agents and

152 paraprofessionals) and 113 of their local supervisors furnished information concerning their own background, training and activities, and perceptions of program operation. Because the programs studied are based on the principle of one-to-one contact, field staff also were able to draw on their records, progress reports, and personal familiarity with each participant to provide data on the characteristics, resources, participation levels, and sales revenue improvements attained by more than 4,500 farmers participating in small farm programs. This sample represented 76% of the farmers assisted on an intensive basis by field worker respondents. Data were subsequently tabulated so that responses for each farmer were linked to responses of the appropriate field worker, local supervisor, and state program leaders.

Most extension administrators and program leaders indicated that their small farm programs were oriented toward farmers with resources and incomes lower than those of farmers served by other extension programs. Our inventory confirmed that small farm program participants typically do have low incomes, limited farm resources, and moderate educational levels. To illustrate, off-farm income amounted to less than $5,000 for 62% of the participants, yet 70% of the participants were estimated to gross less than $5,000 annually in farm sales. Farm size averaged 108 acres. Approximately 37% of the participants had completed less than eight years of schooling. Three-fourths of the participants had ten or more years of farm experience, but less than one-third had received extension assistance prior to their involvement in a small farm program. Some 59% of the participants were black, partly reflecting the greater incidence of low incomes among minority as opposed to white small farm operators and, partly, the emphasis placed on small farm programs by 1890 land-grant institutions.

The types of individual assistance received by small farm program participants are summarized in table 1. While most small farm programs emphasized similar long-term goals, cited previously, they often differed with respect to short-term objectives. For example, some concentrated on upgrading production practices, others emphasized market development, and still others focused on improvement in home gardening. State programs, and often localities within a program, also varied widely in formal and informal administrative processes, commitment of professional staff and financial resources, and characteristics of field staff.

Table 1. Types of Individual Assistance Received by Participants during the Period of Their Association with a Small Farm Program, Southern Region of the United States, 1977

Program Objective/Type of Assistance[a]	Percentage of Participants[b]
Improve gardening and other food production for home use	42.6
Improve production practices:	
soil testing	67.7
crop production	47.7
livestock production	43.5
Improve enterprise management:	
develop farm records	28.7
develop farm plans	24.3
increase enterprise size	13.8
eliminate enterprises	13.5
add new enterprises	12.6
Increase participation in government programs:	
nonextension agricultural programs	27.9
extension programs	21.4
social programs	5.5
Improve facilities:	
family housing	18.5
farm buildings	16.1
Improve marketing:	
increase quality of product outputs	28.9
expand available markets	17.3

[a] Most farmer-participants received more than one type of assistance.
[b] Indicates assistance at least once during the period of a farmer's association with a small farm program. No distinctions were made as to the intensity or duration of the assistance provided.

Method of Analysis

Analysis of program effectiveness was complicated by the diversity of short-term objectives enunciated by state and local personnel, by the wide range of program characteristics that could affect success measures, and by the equally large number of factors extraneous to the programs that could also influence outcomes (Weiss; Wholey et al.). Our analysis focused on field staff estimates of changes in participants' farm sales revenue during the period of their association with a small farm program. Although this measure is directly related to many long-term program goals, it is not the only indicator of program success. Other activities, for example improving home gardening, are not necessarily reflected in farm sales increases.

To overcome some of the difficulties inherent in comparing the outcomes of diverse program efforts, a conceptual model was developed to explain the degrees of improvement in farm sales revenue experienced by small farm program participants. Changes in farm sales revenue may be responsive to such nonprogram factors as output prices, environmental effects on per acre or per animal yields, and farmer resource bases. Reve-

nue changes also were hypothesized to be sensitive to the level and intensity of a farmer's small farm program participation, either as a result of technical assistance provided by field staff or through an induced change in the farmer's resources. Levels of program participation in turn may be influenced both by farmer receptivity to assistance and by the availability and attractiveness of program activities. The latter two factors are largely controlled by the ability of supervisory and field staff and by program design and fiscal resources, each of which is partly dependent upon federal and state administrative decisions and commitments.

To test these hypotheses and to estimate the effects of various factors on small farm program outcomes, it would have been desirable to employ the available cross-sectional data by regressing farmers' sales volume changes against all the measured factors hypothesized to determine the changes. This approach would minimize specification bias resulting from exclusion of relevant variables. On the other hand, the large quantity of factors thought to affect the sales revenue increases attained by participants implies that such a strategy would result in extensive collinearity among regressors, and hence unduly wide standard errors for some or all coefficient estimates (Kmenta, pp. 338–39).

As an alternative, two approaches were followed. In the first approach, sales volume determinants were divided into blocks of variables and observed changes in participants' sales volume were regressed against each of these blocks separately. The blocks utilized were (*a*) the farmer's physical and human resources at the time he joins a program, (*b*) the levels and types of his participation in an extension small farm program, (*c*) the characteristics of local program staff, and (*d*) local and statewide program characteristics. Measures of output price and environmentally affected yield changes were retained in each equation. In the second approach, factors having especially important implications for program implementation or policy formulation were selected from each block and combined in a single, unified regression model. This approach allowed the effect of each selected factor to be measured in the presence of variables from other blocks.[1]

Results

A summary of the results of the second approach is shown in table 2, where variables are grouped according to the blocks discussed above. The mean value of the dependent variable ($1,169) is consistent with expectations of program supervisory and field staff that many participants would improve farm sales revenue, but that the increases would be modest in most cases. The initial "control" block is a set of zero-one variables that reflect whether output price changes or adverse weather conditions were considered by field staff to have been an important factor affecting participants' sales volume changes. Thus the control variables qualitatively account for the impacts of these external factors on program outcomes.

The second group of variables in table 2, comprising participants' initial farm sales and off-farm income, represents the farm resources block. Increases in participants' farm sales revenue were, on average, greater among farms with relatively high initial sales levels and among farmers with relatively high off-farm incomes. In our earlier analysis, when only farm resource variables were included in the regression model (not shown here), sales increases were also greater for younger farmers and for those with relatively more education. Thus, participants' sales improvements are partially determined by their resource characteristics, implying attributes of the selected target audience should be considered in setting realistic program goals.

In the third or program participation block of table 2, two sets of zero-one variables are used to reflect the nature of a farmer's involvement in a small farm program. The first set identifies whether a farmer attended meetings only, events only, or a combination of both. Results indicate that farmers who participated only in educational meetings did not experience greater sales revenue increases than a base group participating in no group activities, while farmers participating only in events, such as farm tours, were associated with sales revenue gains averaging $169 greater than in the base group. Farmers participating in both meetings and group events were associated, on average, with sales increases nearly $215 greater than those of farmers participating in neither.

The second set of zero-one variables in the program participation block identifies the types of individual program assistance received by a participant during the period of his involvement in a small farm program. Farmers receiving assistance in farm production practices, and those receiving assistance in farm planning or resource management, were associated with farm sales increases $337 to $380 greater than a base group which received only such nonfarm assistance as in garden production or house repair. Those receiving assistance in the use of agricultural agencies or in marketing improvement also earned greater sales volume increases than in the base group, but only in the magnitude of $133 to $201. Regardless

[1] Estimation of several models which included interaction terms (measuring the effect of participants' resources on the responsiveness of farm sales revenue to program participation) provided some additional information on program strategies, but did not basically alter results of the model presented here. Collinearity problems were amplified by inclusion of interaction terms.

of the type of participation, the level of a farmer's interest in the program (as perceived by the field worker and rated on a scale of one to five) strongly affected the outcome associated with that farmer. Sales revenue increases were also positively affected by the length of a farmer's participation in a small farm program.

The fourth group of variables in table 2 de-

Table 2. Effect of Output Prices, Environmentally Related Yield Fluctuations, Farm Resources, Program Participation, Staff Characteristics, and Program Characteristics on Farm Sales Revenue Increases of Participants in Small Farm Programs, Southern Region of the United States, 1977

Variables[a]	Unit	Coefficient (*t*-value)
Price and environmental block		
Variable equals 1 if field staff said indicated factor affected revenue changes, 0 otherwise. (Base: neither prices nor weather.)	output price increase	97.10 (1.76)
	output price decrease	−489.43 (−4.00)
	adverse weather	−418.29 (−5.67)
Farm resource block		
Farm sales volume during the year prior to participation	$1,000	69.39 (16.31)
Off-farm income of family members, 1977	$1,000	26.82 (4.51)
Program participation block		
Group activities: variable equals 1 if farmer participated at least once in indicated activity, 0 otherwise. (Base: neither meetings nor events.)	meeting(s) only	[c]
	event(s) only	169.12 (2.14)
	both meeting(s) and event(s)	214.39 (3.24)
Individual assistance: variable equals 1 if farmer assisted at least once with indicated practice, 0 otherwise. (Base: gardening, home repairs, use of social service agencies.)	crop or livestock production practices	336.88 (4.02)
	farm planning or resource management	382.16 (7.73)
	use of other extension programs or agricultural agencies	132.97 (2.62)
	marketing	201.04 (4.10)
Field staff assessment of farmer interest in program	index 1 through 5 (1 = poor, 5 = excellent)	160.64 (5.73)
Duration of farmer association with program through 1977	years	79.98 (4.20)
Field staff characteristics block		
Age in 1977	years	[c]
Formal education through 1977	years	−25.49 (−3.62)
Experience in farm operation through 1977	years	13.88 (6.54)
Program characteristics block		
Agricultural training for field worker, 1977	days	1.76 (1.66)
Supervisory assistance for field worker, 1977	days	61.22 (5.90)
Influence of field worker ability on effectiveness of assistance received	interaction term[b]	−15.85 (−5.92)
Local supervisor assessment of field worker ability	index 1 through 5 (1 = poor, 5 = excellent)	277.61 (5.76)
Length of employment of field worker through 1977	months	3.46 (4.29)
Equipment and demonstration funds, 1977	dollars	[c]
Farmers assisted per field worker, 1977	number	−5.56 (−3.90)
Intercept		−1,729.47

[a] R^2 = .316. There were 1,874 degrees of freedom for the *t*-tests. Observations were deleted from the sample if there were missing values for any of the independent variables. The dependent variable was expressed in dollars; its mean value was $1,169 and its range was −$1,000 to $3,750.

[b] This variable is a cross-product of the second and fourth variables listed under the program characteristics block.

[c] Not significant at the .05 level in initial regressions and excluded from the model reported.

scribes characteristics of the field staff contacting the farmer. A field worker's success in inducing farm sales volume increases appeared to diminish with formal education, but to increase with years of farm experience. In the field staff characteristics block model (not shown here) significant relationships also were found between field workers' age, sex, and ethnic background and their success at inducing sales revenue improvements. These results suggest that selection of field staff provides program leaders with an important mechanism for influencing program effectiveness.

The final group of variables in table 2, taken from the program characteristics block, reflects the influence of local program resources and field staff training, supervision, and workload on participants' farm sales improvements. Agricultural production training received in the past year by a field worker, and assistance provided by local supervisors and other extension professionals, were positively associated with farm sales improvements realized among farmers contacted by the field worker. Impact of supervisory assistance varied negatively with field workers' ability (as evaluated on a scale of one to five by his local supervisor). That is, another day of professional assistance to a field worker with a low rating (1) was associated, on average, with $48.36 greater farm sales improvements among farmers assisted by that worker. But another day of assistance to a field worker with the highest rating (5) was associated with a $15.02 decrease in farm sales improvements, implying that, at the margin, direct professional assistance may interfere with efforts of higher quality field staff. This suggests that the level of supervisory input into small farm programs ought to be determined at the local level and related to the needs of individual employees.

Field workers' ability itself was positively associated with program success, as was months of staff experience on the job. However, no significant relationship was found between program effectiveness and availability of financial resources to purchase equipment or demonstration supplies. Finally, field staff performance declined only slightly with increasing workload. Field workers reported working intensively with an average of thirty-two farmers during 1977. For every additional farmer assisted by a field worker, average annual sales increases experienced by the farmers associated with that worker declined by $5.56. This implies that within the workload range reported by field staff, program funds might be more effectively utilized if the number of farmers assisted by the average field worker were increased.

Discussion

The results of the unified regression analysis suggest that small farm program success is influenced by a large number of variables, many of which may be controlled by program planning and implementation processes. For example, the results illustrate the importance to program outcomes of policy choices regarding program location and target audience orientation. They also provide guidelines for administrative decisions on field staff employment and on the provision of financial and professional support resources, factors which potentially affect program achievement. Nevertheless, the relatively modest R-square (.316), although not particularly low for cross-sectional models of this type, indicates that much of the variation in program outcomes is determined either by factors for which adequate measures were not achieved or by presently unmeasurable human elements.

Based on the survey responses and an examination of *Census of Agriculture* data, extension small-farm program participants are representative of the approximately 200,000 small farm operators in the South with low total incomes (U.S. Department of Commerce). Currently, the programs serve only a limited proportion of these farm operators. The results show that observed increases in sales revenues are generated in substantial part by the level of participation in, and the quality of, small farm program activities. When such other benefits as improved home food production, increased operator skills, and greater farmer social participation are considered as well, the performance of carefully planned and executed small farm programs appears favorable. Further research to evaluate small-farm program costs and benefits, and to compare these program outcomes to results of alternative assistance approaches, would be useful. However, in the absence of such studies, the present evaluation suggests that expansion of small farm programs merits consideration as a means of assisting limited resource farm families.

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References

Atkinson, R. "Georgia Small Farm Program: A Progress Report." Mimeographed. Dep. Agr. Econ., University of Georgia, July 1976.

Enlow, G., C. George, J. Holik, and E. Wiggins. "Missouri Small Farm Family Program: 1977 Preliminary Progress Report." Mimeographed. University of Missouri Coop. Extens. Serv., 1978.

Kmenta, J. *Elements of Econometrics.* New York: Macmillan Co., 1971.

Maddox, C. L., R. F. Jones, and C. H. McDaniel. "Demonstrations on Limited Resource Farms in Alabama." Alabama Coop. Extens. Serv. R-14, 1969.

McAfee, D. H. "Farm Opportunities Program." Mim-

eographed. North Carolina Agr. Extens. Serv., Sep. 1975.

Orden, D., S. T. Buccola, and P. Klobus Edwards. "Cooperative Extension Small-Farm Programs in the South: An Inventory and Evaluation." Res. Div. Bull. 153, Virginia Polytechnic Institute and State University, 1979.

Stewart, F. J., H. Hall, and E. D. Smith. "Potential for Increased Income on Small Farms in Appalachian Kentucky." *Amer. J. Agr. Econ.* 61(1979):77–82.

Strickland, C. L., and M. Soliman. "Nonprofessional Aides in Agriculture, An Evaluation of a Program in Cooperative Extension Education for Small Farm Families." Bull. B-1165 (PV), Prairie View A&M University, 1976.

U.S. Department of Commerce. *1974 Census of Agriculture, State and County Data.* Washington, D.C., 1977.

Weiss, C., ed. *Evaluation Research: Methods of Assessing Program Effectiveness.* Englewood Cliffs, N.J.: Prentice-Hall, 1972.

West, J., V. R. Harrold, K. C. Schneeberger, and L. Williamson. "Missouri Small Farm Program, An Evaluation with a Control Group." Dep. Agr. Econ. SR176, University of Missouri, Oct. 1975.

Wholey, J. S., et al. *Federal Evaluation Policy.* Washington, D.C.: Urban Institute, 1976.

Wiggins, E. R. "Small Farm Development Programs." Dep. Agr. Econ. Pap. 1972-8, University of Missouri, Jul. 1972.

An Integration of Industry and Classroom in Graduate Research: A Case Study

Daymon W. Thatch

With students' requests for relevancy and employers' desire to hire students with practical experience, there has been a resurgence of interest in courses and programs both at the graduate and undergraduate level which provide this type of environment for students (Devino, French, Luby, Snodgrass, Thomas). As Snodgrass and others have noted, work experience education has taken a variety of forms and goes by various names. However, almost all involve the concept of off-campus work or study organized by the university with a private business or government agency for which academic credit and/or pay is received by the student.

Off-campus, work-study programs in agricultural economics at an undergraduate level have been fairly popular since the mid-1970s, and several authors have called for more programs (Downey, Epp, and Kneckel). "Few similar programs have been operated at the graduate level." And furthermore, "the benefits would appear to be at least as great for graduate students as for undergraduates" (Devino, p. 580).

The purpose of this paper is to report and evaluate an ongoing graduate research program that has used a number of company and governmental researchers to help students contrast similarities and differences and gain a better understanding of university, industry, and government research.

Philosophical Background

The overall need for an integrated work-study academic program and the virtues of such a program have been well-documented (Stutz and Knapp). As a starting educational position, the author makes three assumptions: first, educational programs should equip graduates with the ability to perform on the job, grow in a given position, and help develop a philosophy that will assure a personally satisfying and productive role in society. Second, education is not a neatly packaged item to be taken home and consumed. Third, within this framework it is the task of educators to develop programs and provide guidance to help meet the needs and desires of students and to provide understanding and ability to function within the given profession.

Industry-Classroom Research Program

In 1971, efforts were initiated to develop an integrated industry-classroom program that would encompass this overall educational philosophy. This paper develops the need, procedure, and preliminary results of the program.

Why Such a Program?

Three facts became apparent to the author after he taught a graduate introductory research methods course for two years. First, an introductory course in research is best taught as a blend of philosophical and analytic approaches which stress fundamentals and common sense; second, although students could learn the concepts and approaches, to understand research they should have some practical applied experience; and third, although students are often technically trained they are unprepared in terms of lines of authority and job expectations for industry or government employment.

In short, although the students receive adequate training in the philosophy, concepts, and approaches to research via formal class lectures, discussions, research report writing, and library searches, they need an applied project that uses the formal ideas in a setting that they will encounter after graduation. The field experience project was initiated to fill this gap.

Field Experience Contacts

In an effort to set up realistic, current, field experience problems, the following procedures were used. The author initially contacted the director of marketing research (or research) of a number of major companies in the local area. The directors were asked, by phone, if they would be willing to spend about two hours in a student experiment to help masters degree candidates understand the nature and problems of industrial or government research. If they were agreeable (and all but one contacted over a seven-year period were) they were asked to submit, on a confidential basis, several past or current projects so that the author could screen them as a possible study project for student research teams.

The second step was for the instructor to meet personally with the researcher at his or her office. This meeting provided a chance to get acquainted

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and assure the researcher that the main purpose of the project was to help students better understand research. In addition, this visit provided the opportunity to explore various approaches and techniques used by individual researchers and to obtain initial information and background data on several potential student research projects. A number of other details also were accomplished at this time, such as checking researcher's availability and obtaining clearance for materials, security passes for students, parking. At the conclusion of the meeting, the researcher was told that he or she would be sent a letter stating the major purpose of the project (an experiment to provide students with insights into company research), confirming date of the student group interview, a copy of the charge given to the group (analyzing and evaluating the company's selected research project), and a statement specifying that materials would be returned and that no written or oral report outside of the classroom would be made with the materials.

Student Projects

From two to four students were organized into research groups using four criteria: selected areas and techniques to be used on masters degree research, general interest, backgrounds, and special skills they possessed. Individual projects were explained to each group. They were given a specific company project and data minus the results and recommendations. In short, each team was given a problem and objectives as stated, along with relevant background and collected data, and asked to do their own analysis and answer specific questions and to draw conclusions to the research and make recommendations.

In addition, each group was given two further tasks. First, they were to develop a background profile on the company and/or division within the company, and, specifically, to pinpoint the company's major goals and overall operating and growth philosophy. This was achieved by evaluating annual reports and other available information used for recruiting. Second, they were asked to obtain information, by interview, on the researcher's philosophy of research and the methods and techniques he or she found most beneficial in doing research.[1]

Before the interviews were held, student groups were given several weeks to obtain information about the companies and to analyze the assigned research project. This time lag allowed the interviews to be held in two to three hours and enabled the students to prepare relevant questions about their specific projects in advance.

Company Interviews

Although cost and time considerations may indicate that a visit of the researcher to the university would be more practical than taking a group of students to the researcher, the latter method was chosen. It was felt that the students would benefit substantially by observing the researchers in their environment, by being exposed to the available facilities, to reference sources, and to the physical position of the researcher in reference to other managers within the company environment. A second benefit of visiting the off-campus research facilities was that in almost all interviews, other researchers involved in the project were asked to join in the meeting. This added insight into the project and exposed the student groups to additional research approaches and philosophies.

In terms of the formal interview, researchers were asked to start by discussing their overall companies' goals and philosophy and then their individual philosophy and approaches to research. These introductory remarks were followed by specific student questions on their assigned project. All of the interview sessions were attended by the instructor-author so that the discussion could be rechanneled if necessary, and, further, to obtain first-hand insights of other researchers' approaches.

Student Group Reports

Computer time and assistance were provided to individual student groups. Although each group team member was asked to analyze, write, and present a part of the final report, it was stressed that the group as a whole was responsible for the overall report and recommendations.

Written reports were submitted to the instructor two days prior to the oral class presentation to allow time for preparation of discussion questions that might not surface during the class. The oral presentation could take any form so long as all the items stated in the project charge were covered and sufficient information was given so that the class could understand the project being evaluated. Questions were encouraged on all phases of the analysis and recommendations.

After the written and oral presentations were given, groups were asked to consider comments and discussion and revise reports, if necessary, so that a final draft could be prepared for submission to the company.

The six steps of the project can be summarized as follows: (*a*) contact researcher for willingness to cooperate in student research experiment; (*b*) arrange a personal meeting with researcher to detail

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[1] In an introductory research course one of the most difficult tasks is to get students to master the art of defining researchable problems and explicitly stating testable realistic hypotheses. Although a large amount of time in the introductory research methods course is spent on this area, for the field experience project students were given a completed or on-going company research project and asked to evaluate the given research problem and objectives using the formal knowledge obtained in the classroom and in view of company goals and philosophy.

objectives of research experiment and obtain potential company research projects for student groups; (*c*) confirm meeting date, select specific company project that students will evaluate, and set up specific students' project questions; (*d*) meet with researcher(s) at their facilities to answer students' questions on evaluation charges and to obtain company's and personnel goals and philosophies; (*e*) have students submit final written report and orally present results of evaluation and other questions to class for discussion; (*f*) send the confidential student evaluation of the company's research report to company and a letter of appreciation and return the data borrowed to participating company.

Evaluation Comments

The graduate industry-classroom experience program has been in process for seven years. During this period, twenty-three separate student groups have met with both government and business researchers. The results have been excellent and the author concurs with Snodgrass' comments, "There are no significant disadvantages to any party from the offering of work-study programs" (p. 1162), except perhaps in the additional time resources of the teacher. Industry cooperation has been excellent, student enthusiasm high, and from a teaching perspective, students are obtaining applied experience in research and insights into other practical problems they will encounter in business.

In an effort to communicate more systematically the benefits of the program, four areas will be listed: student benefits, instructor benefits, company researcher benefits, and evaluations.

Student benefits include: (*a*) increases interest and motivation by working on meaningful, "real world," research problems—one gains appreciation of alternative research approaches and data sources available; (*b*) helps one to learn self-discipline, responsibility, and how to plan, work as a member of a team, complete a project, and work against deadlines; (*c*) allows one to observe philosophies and goals of companies and researchers to see how these manifest themselves in their research efforts; (*d*) helps one minimize the "culture shock," that is, the way the business research and methods often deviate from the world of academic research; (*e*) develops confidence in one's ability to think, analyze, and evaluate the work of others, and to understand the problems, frustrations, and rewards of research.

Instructor's benefits include: (*a*) helps achieve the learning objectives of the course—in this case, to allow students a chance to evaluate a hand-on practical applied research project and a chance to observe how industry research is conducted by various researchers; (*b*) stimulates the instructor as class becomes more exciting with motivated students studying current "real world" problems; (*c*) obtains insights from interchange with several current applied researchers in terms of current state of the art, available data, and present research needs; (*d*) makes excellent contacts for future class projects, possible student job opportunities, and instructor consulting.

Company-researcher benefits include: (*a*) good researchers seem constantly to desire input and opinions on their current research approaches—this input seems especially valuable when it is relatively free of cost and comes with very little risk of harmful effects; (*b*) researchers also desire the opinions of students as a source of input to add to the sample size of a given survey (often the students of a different generation are "in tune" to ideas or values that may have been overlooked or downgraded by the researcher); (*c*) public relations is important for companies and allowing students to understand company philosophies and goals and to see the effort they expend in research is one valuable component; (*d*) researchers and companies get a look at potential candidates for future positions, and keep in contact with university graduate programs.

Evaluation

In evaluating the above industry-classroom experience approach, only subjective methods have been employed. Student evaluations have been most gratifying in their praise for the project and the insights that have been gained. Positive feedback has been noticeable in the zeal students exhibit in their group assignment and the effort they expend above and beyond that necessary to obtain a grade. Former students on numerous occasions have indicated that the project was one of the highlights of their graduate program.

From the instructor's viewpoint, the industry-classroom experience has more than met the objectives of the course. The uniqueness of this program procedure appears to be the ability to tie together "real world" research and some of its constraints to the formal research methodology taught in an introductory research methods class. This marriage is achieved with minimal direct cost and time away from the classroom. Prescreening of company projects has ensured that the graduate students can understand the projects with very little background and that a variety of project types are available for analysis. Individual projects have been analyzed in consumer product acceptance, product demand, pricing strategies, elasticity evaluation, and investment project alternatives. Analytic techniques have ranged from factor and chi-square analysis to econometric models and evaluations of the major survey methods (mail, personal, and telephone) as well as direct experimental designs.

On the other hand, to be successful, the experience-research project takes considerably more time to prepare than class lectures in research. To be successful, class size must be held to

less than twenty-five students because contact work needed for one instructor to set up experiences becomes overburdening. Furthermore, although the direct travel cost has been fairly small because of the short distances (two to fifteen miles) to the companies, there are other added costs such as telephone, postage, and secretarial time.

High acceptance of the program is indicated by the fact that only one company out of twenty-four has turned down the offer to participate in a project with students. Furthermore, of the ones who have participated, most have said that they look forward to participating in future projects.

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References

Devino, Gary T. "A Pilot University-Industry Master's Training Program." *Amer. J. Agr. Econ.* 59(1977): 580–82.

Downey, W. D. "The Role of the Academic Institution." *Amer. J. Agr. Econ.* 57(1975):799–802.

Epp, Donald J. "A New Degree is Needed: Master of Agricultural Economics." *J. Northeast. Agr. Econ. Council* 6(1977):16–22.

French, Charles E. "Selected Alternative Programs for Bringing the Real World to the Undergraduate Classroom." *Amer. J. Agr. Econ.* 56(1974):1163–75.

Knechel, John A. "Agricultural Economics and Industry—The Relevancy Gap." W. Agr. Econ. Assoc. annual meeting, Corvallis, Ore., 21 July 1979.

Luby, Patrick J. "Perspective from the Meat-Packing Industry." *Amer. J. Agr. Econ.* 57(1975):791–95.

Snodgrass, Milton M. "Off-Campus Work and Study Experience Programs for Undergraduate Students in Agricultural Economics and Agricultural Business Management." *Amer. J. Agr. Econ.* 56(1974):1153–62.

Stutz, Jane, and Joan Knapp. *Experimental Learning: An Annotated Literature Guide,* Annotated Bibliographies, Wisconsin Assessment Center Handbook. Green Bay: Office of Educ. Res. and Develop., University of Wisconsin, 1978.

Thomas, William R. "Experimental Education and Educational Management." *1977 Summer Work Conference—The Impact of Changing Students: An Assessment,* University of Arkansas, July 1977.

The U.S. Pear Market

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Pears are the second most important deciduous fruit produced by U.S. farmers. They are particularly important in the Pacific Coast states of California, Oregon, and Washington, which have increased their share of total U.S. production in the last quarter century from 89.3% in 1949–51 to 94.5% in 1975–77. About half of all pears are shipped fresh to distant markets, while the remainder are canned or dried so that pear production is of concern to fruit packing, freight and distribution firms throughout the United States, and to processing firms in scattered localities throughout the Pacific Coast states.

About 70% of all U.S. pear production since 1949 has been Bartletts, mostly centered in the Pacific Coast states, especially California. A small proportion of Bartletts are grown in Michigan, New York, and Pennsylvania. Accordingly, a number of previous authors, including Pubols, Edwards, Ricks and Edwards, Kourouklis, and Hoos and Kuznets, have treated Pacific Coast Bartlett pears as a separately identifiable industry. The majority of Pacific Coast Bartlett pears (usually over 70%) each year are processed, mainly in canned form. The remainder are sold fresh.

Most other pear varieties are harvested later than Bartletts and are sold primarily for fresh use. Commonly called "winter" pears, the other main varieties are D'Anjou and Bosc. About 95% of winter pears are grown in the Pacific Coast states, primarily in Oregon and Washington. The share of the national pear market accounted for by winter pears has declined in the last quarter century from 27.3% to 21.2%.

While the general level of pear production has been relatively stable over the last three decades, output has been erratic from year to year. For the 1949–74 period, Masud, O'Rourke, and Harrington found a coefficient of variation of 13.7% for annual production of all U.S. pears and 16.9% for Pacific Bartletts. The number of bearing trees of both Bartlett and other varieties at the 1974 census was the highest for twenty years, but the number of nonbearing trees had declined rapidly since 1964, indicating that the surge of new plantings in the 1960s had not been continued into the 1970s.

Changes in annual average prices generally have been related inversely to changes in production. In the period 1963–68, the weighted average price of all pears exceeded $100 per ton at 1967 prices in five of the six years. In contrast, that price level has been exceeded in only two of the last ten years. Pear producers have been in a quandry about whether to increase or reduce acreage, which varieties to give preference to, whether to increase or reduce processing utilization, or what institutional changes might be made to improve prices and incomes.

Objectives

The objectives of this study were to (*a*) estimate annual farm level prices of Pacific Coast Bartlett pears in processing and fresh markets, (*b*) determine the relationship between demand for Bartlett pears and that for other Pacific Coast pears and other U.S. pears excluding Pacific Coast, (*c*) determine the optimum allocation of a predetermined quantity of Pacific Coast Bartlett pears between fresh and processing uses, and (*d*) predict the price impact of possible future developments in the U.S. economy and the U.S. pear industry.

The last study of the U.S. pear industry to take such a comprehensive view was that by Pubols, who used data up to and including 1954. Pubols studied the factors affecting the annual average price of all Pacific Coast pears, fresh Pacific Coast Bartlett pears, canned Pacific Coast Bartlett pears, Pacific Coast pears other than Bartlett, and pears other than Pacific Coast. All variables were converted into first differences of logarithms and price equations estimated using ordinary least squares. Pubols analyzed relationships for 1925–42, 1942–54 and for the entire period 1925–54. In general, all prices were negatively and significantly affected by own-quantity and 1 June stocks of canned pears, and positively affected by income. Pubols found little evidence of mutual impact of other U.S. pear production on Pacific Coast pear prices, but Pacific Coast Bartlett prices were significantly affected by production of other Pacific Coast pears.

We were interested in seeing whether the relationships reported by Pubols still held in the U.S. pear industry more than two decades later. However, because of our broader objectives, the impact of inflation since 1954, and the need to take into account simultaneity in price determination and

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processing allocation, our model formulation differed considerably from that used by Pubols.

Edwards' 1965 study, which looked separately at demand for Bartlett pears from California and those from Oregon and Washington, concluded that they were a homogeneous commodity in terms of market behavior. Ricks and Edwards were concerned primarily with the Pacific Coast Bartlett pear industry. Kourouklis mainly investigated intraseasonal aspects of demand for Oregon Bartlett pears. Hoos and Kuznets' contribution has been an annually updated formula for predicting the FOB price of canned Bartlett pears, which formula is used in price negotiations between growers and canners. Thus, our model differs from the above in period covered, basic goals, and intended use of the results.

Economic and Statistical Model

Because our study focused on determination and prediction of price and of product allocation at the farm level, our economic model did not attempt to analyze the entire pear production and marketing system. It was necessary to assume that supply in any year was predetermined and that the relationship between farm level demand and retail demand was constant over time. The U.S. Department of Agriculture series on canned pears show that for the five-year intervals 1964–68, 1969–73 and 1974–78, marketing margins averaged 77.8%, 78.0%, and 78.2% of retail price. Accordingly, our assumption about the farm-retail relationship appears reasonable.

Originally, following Pubols, it was assumed that allocation of Pacific Coast Bartlett pears, and prices for Pacific Coast Bartlett pears, other Pacific Coast pears, and other U.S. pears would be determined simultaneously. If price of processing Bartletts rose, the quantity allocated to processing would rise and the supply available for fresh market fall, thus affecting fresh market price. In a similar manner, it was hypothesized that the demand for fresh Bartlett pears would be interrelated with the demand for other Pacific Coast pears and other U.S. pears which go primarily to the fresh market. However, since the period studied by Pubols, Pacific Coast Bartletts have become increasingly dominant in the national pear market. Accordingly, in preliminary analysis, we found that for the 1949–77 period the significant influences were unidirectional. Bartlett pears affected the demand for all other pears but not vice versa.

The economic model which best described the U.S. pear industry included a demand and an allocation equation for both fresh and processed Pacific Coast Bartlett pears, a demand equation for other Pacific Coast pears, and a demand equation for other U.S. pears—six equations in all, as follows:

Pacific Coast Bartlett Demand Equations

(1) Processed:

$$Y_1 = f(Y_3, X_1, X_2),$$

(2) Fresh:

$$Y_2 = f(Y_4, X_2, X_3).$$

Pacific Coast Bartlett Allocation Equations

(3) Processed:

$$Y_3 = f(Y_1, Y_2, X_4, X_5),$$

(4) Fresh:

$$Y_4 = f(Y_1, Y_2, X_4, X_5).$$

Other Pear Demand Equations

(5) Other Pacific Coast:

$$Y_5 = f(X_1, X_2, (X_4 + X_6), X_7),$$

(6) Other U.S.:

$$Y_6 = f(X_2, (X_4 + X_6), X_7).$$

The Ys indicate endogenous variables and the Xs, predetermined variables. To remove the influence of changes in population and general price level over time, all quantity variables were converted to tons per 1,000 people and all price and income variables were suitably deflated, grower prices by the wholesale price index, personal disposable income per capita by the consumer price index: Y_1 is grower price of processed Pacific Coast Bartlett pears ($/ton); Y_2, grower price of fresh Pacific Coast Bartlett pears ($/ton); Y_3, quantity of Pacific Coast Bartlett pears allocated to processing; Y_4, quantity of Pacific Coast Bartlett pears allocated to fresh; Y_5, grower price of other Pacific Coast pears ($/ton); Y_6, grower price of other U.S. pears ($/ton); X_1, stocks of canned pears, June 1; X_2, disposable personal income per capita, U.S.; X_3, quantity of U.S. fresh nectarines; X_4, total production, Pacific Coast Bartlett pears; X_5, trend (= 0, 1949, = 1, 1950 . . .); X_6, total production, other Pacific Coast pears; and X_7, total production, other U.S. pears.

The price-quantity relationship specified are what economic theory would lead us to expect. Previous research has generated empirical evidence of a negative influence of quantities produced, allocated, or in stock on price. Pubols and Kourouklis have demonstrated the positive influence of income on demand. Our preliminary analysis suggested the influence of a competing seasonal fruit, fresh nectarines, on the price of fresh Pacific Coast Bartletts and of a positive trend factor in the allocation of Bartlett pears to processed uses.

The marketing season for fresh nectarines has more overlap with that of fresh Bartlett pears than

does any other competing fruit. In preliminary analysis the influence of fresh apple supplies was found not significant. The percentage of the Bartlett pear crop allocated to processing has shown an upward trend in the period studied.

Our model consisted of four demand equations, one allocation equation and one identity because with X_4 predetermined, once Y_3 is known, Y_4 is equal to $X_4 - Y_3$. Equations (1) through (3) were estimated using two stage least squares (TSLS), and equations (5) and (6) using ordinary least squares (OLS) under the usual assumptions about the properties of the error terms. All the equations in the simultaneous part of our system were overidentified.

Annual data for the years 1949–77 were used in statistical estimation. Data were drawn from publications of the U.S. Departments of Agriculture and Commerce and of the relevant state agencies. A complete listing is available from the authors.

Statistical Results

In general, the results of the statistical estimation were satisfactory by the usual measures of level of significance and conformity of signs to theoretical expectations (table 1). The value of the t-statistic for each coefficient is reported, although in the case of the TSLS equations, they can be used as an approximate indication of significance. Perhaps the most surprising results were those for income. For both fresh and processed Bartlett price equations, the influence of income was small and positive but the t-value low. For other Pacific Coast pears, the income coefficient was negative and significant at the 5% level; for other U.S. pears, it was negative but not significant. This contrasts with Pubols' findings of a significant positive influence of income on the price of each type of pear.

Some explanation of this discrepancy is in order. Pubols' data covered the period 1925–54, whereas our study examined only postwar conditions for 1949–77. Between 1949 and the mid-1960s, the supply of both Bartlett pears and of all other pears declined so that real price rose while income rose. However, since the mid-1960s, supplies of pears have been rising and real price falling at the same time that real income has continued to rise. The decline in real price has been greater than could be explained by the increase in quantity alone. The income variable may be acting as a proxy for both income effects and changes in tastes, consumer and retailer preferences, etc., which have adversely affected the demand for pears. For example, with a decline in the birth rate since the mid-1960s, a number of major processors in Michigan have discontinued buying pears completely.[1]

When we reran our model for the subperiods 1949–67, 1955–77, and 1961–77, the signs and magnitudes of all coefficients except income were stable. However, the income coefficients on processed Bartlett pears, other West Coast pears, and other U.S. pears became either less positive or more negative the more recent the period studied, but only significantly negative in the case of other West Coast pears. Accordingly, we concluded that our results for the 1949–77 period, by providing most degrees of freedom, and by covering both rises and declines in pear production, gave us the most generally defensible model of the U.S. pear industry for both forecasting and allocation purposes.

June 1 stocks of canned pears strongly influenced the price of processed Bartletts, and fresh nectarine supplies, that of fresh Bartletts. Other Pacific Coast and other U.S. pear prices were significantly influenced by total Pacific Coast and other U.S. pear supplies. Other Pacific Coast pear price was also sensitive to 1 June stocks of canned pears, although the actual process of influence probably is felt indirectly through the effect of canned stocks in the Bartlett pear market.

[1] Thanks are due to an anonymous reviewer for this insight.

Table 1. Estimated Coefficients of the U.S. Pear Model, 1949–77

Dependent Variable	Constant	Independent Variables				Routine	R^2	d
Y_1	291.6313	$-97.0793Y_3$	$-154.0098X_1$	$+0.0071X_2$		TSLS	—	—
	(7.024)	(6.326)	(2.922)	(.834)				
Y_2	195.0333	$-160.3247Y_4$	$-148.8319X_3$	$+0.0192X_2$		TSLS	—	—
	(5.063)	(7.772)	(3.305)	(1.182)				
Y_3	00.0623	$+0.0079Y_1$	$-.0065Y_2$	$+0.6976X_4$	$+0.0080X_5$	TSLS	—	—
	(.113)	(1.854)	(1.441)	(5.065)	(2.443)			
Y_5	370.3193	$-38.9533(X_4 + X_6)$	$-113.5478X_1$	$-.0304X_2$	$-113.2888X_7$	OLS	.813	1.701
	(9.140)	(8.566)	(4.017)	(3.010)	(2.497)			
Y_6[a]	219.4859	$-11.1504(X_4 + X_6)$	$-133.7612X_7$	$-0.0149X_2$		OLS	.568	2.054
		(2.238)	(2.506)	(1.211)				

Note: t-values in parentheses.
[a] 1955–77 only.

Price Flexibilities and Elasticities

Price flexibilities derived from the demand equations were estimated for the mean values of the relevant variables and for the most recent (1977) values, enabling us to compare results across varieties and over time (table 2). In all cases, own-price flexibility of demand was negative and significant. Because pear prices for all varieties tend to approach the same general level from year to year, price flexibility at the mean was greatest where per capita consumption was greatest, ranging from almost 1.958 for processed Pacific Coast Bartletts to 0.412 for other U.S. pears. Flexibility was greater in 1977 than at the mean value for processed Pacific Coast Bartlett pears but less for all other pears.

The price flexibilities for both fresh and processed Pacific Coast Bartlett pears were greater than unity and greater than those reported by Kourouklis although still of the same relative magnitudes, suggesting that diversion of Bartlett pears from processing to fresh markets would increase total revenue to growers.

Income elasticities for both fresh and processed Bartletts were positive and increasing over time although not statistically significant. In contrast, income elasticities for other West Coast pears and other U.S. pears were negative and becoming more so over time. Pubols found large positive income elasticities for all four categories of pears.

Price of processed Bartlett pears was becoming more sensitive to the level of June canned pear stocks and price of fresh Bartlett pears to the sales of fresh nectarines, which have risen rapidly in recent years. The elasticity of quantity processed was greater for processed price than for fresh price, the former positive, the latter negative (table 3). Quantity processed was significantly affected by total production of Bartletts with an elasticity close to unity.

Forecasting Price

A major objective of the study was development of a model which would predict the price of the different categories of pears in the light of changes in population, per capita income, and production of pears. Such a model would be useful to growers and processors prior to harvest in making decisions about price or allocation in any year and would also be capable of predicting the impacts of longer-term changes in economic conditions or production.

The derived reduced form of equations (1) through (4) was used for forecasting because it not only takes account of overidentifying restrictions, but also preliminary experiments on past data showed better prediction results from the estimates of derived reduced form than from the unrestricted reduced form. The OLS estimates were used for forecasting in equations (5) and (6).

In general, tests of goodness of fit of the estimated functional forms for past data were better for quantity than price equations.[2] For variables Y_1 through Y_8, the mean absolute percent error was 13.4, 14.9, 3.4, 9.7, 17.0 and 9.2, respectively. The forecasting equations were also applied to data for 1978, outside the range of data used in estimation (table 4). Our results were encouraging. Errors in forecasts were much below those experienced for the historical period analyzed. This suggests that in 1978, processors and growers agreed on a processing price close to that needed to attract adequate supplies to processing. In general, it appears that our model can estimate fairly precisely the likely allocation of Bartlett pears and the general direction

[2] These tests do not measure the extent of the variation in the price forecasts which is due to variation in the exogenous/predetermined variables. It is hoped in subsequent work to apply the method suggested by Feldstein for measuring that source of variation.

Table 2. Price Flexibilities of Demand Computed at Mean Values and at 1977 Values, for Pears of Different Variety and Origin, 1949 to 1977

Type of Flexibility	Value at Mean	1977 Value
Price with respect to own quantity:		
Processed Pacific Coast Bartletts	−1.958*[a]	−3.187*
Fresh Pacific Coast Bartletts	−1.315*	−1.070*
Other U.S. pears	−0.412*	−0.270*
Price with respect to income:		
Processed Pacific Coast Bartletts	0.193	0.390
Fresh Pacific Coast Bartletts	0.479	0.847
Other Pacific Coast pears	−0.777*	−1.410*
Other U.S. pears	−0.386	0.459
Price with respect to 1 June canned stocks:		
Processed Pacific Coast Bartletts	−0.407*	−0.676*
Other Pacific Coast pears	−0.283*	−0.423*
Price with respect to fresh nectarine sales:		
Fresh Pacific Coast Bartletts	−0.424*	−1.402*

[a] Asterisk denotes derived from coefficient with t-value > 2.0.

Table 3. Elasticities of Processing Allocation Computed at Mean Values and at 1977 Values, Pacific Coast Bartlett Pears, 1949 to 1977

Type of Elasticity	Value at Mean	1977 Value
Processing allocation with respect to:		
Processed Bartlett price	0.392	0.240
Fresh Bartlett price	−0.352	0.247
Total production, Pacific Coast Bartletts	0.933*[a]	0.874*

[a] *, is derived from coefficients with t-value > 2.0.

of change in prices of all four pear categories discussed.

Optimum Allocation of Pacific Coast Bartletts

Pear growers are concerned about how to allocate a given crop between fresh and processed uses to maximize their gross revenue. Our model can be used to identify such an optimum point for growers, recognizing that processors, consumers, and society as a whole will not also be at an economic optimum at that point.

Defining V, the total returns by

$$\text{Max } V = \hat{Y}_1\hat{Y}_3 + \hat{Y}_2\hat{Y}_4,$$

subject to demand functions (1) and (2) and the identity, $Y_4 = X_4 - Y_3$, the problem can be reformulated to solve for Y_3, the estimated processing allocation that would earn a maximum total return to growers. On average, the optimal solution for growers would require a reduction of processing allocation by about 9% and an increase in the smaller fresh allocation by almost 26%. The model suggests that total sales revenue to growers over the entire period could have been increased by 4.6%, or 60 million 1967 dollars above that actually achieved. While this gain is substantial, many growers would be reluctant to change established institutions and practices in order to achieve it. However, the optimal allocation was becoming increasingly more beneficial in recent years. In the first eight seasons of the 1970s, optimal revenue exceeded actual by 10.8%. This outcome is consistent with the results reported in table 2, which showed the price flexibility of processed Bartletts increasing and of fresh Bartletts decreasing.

Summary and Conclusions

Our econometric model suggests that average income elasticities in the 1949–77 period were low for Bartletts and negative for all other pears. In contrast, for the earlier 1925–54 period, Pubols found positive and significant income elasticities for all four categories of pears studied. The indicated negative income elasticities logically can be expected to discourage expansion of production of varieties other than Bartletts in the Pacific Coast states and in the rest of the United States.

Our finding of higher price flexibilities for processing Bartletts than for fresh Bartletts suggests that grower returns could be increased by allocating a greater proportion of the total Bartlett crop to fresh market. Our model can also be used to forecast price and allocation of pears for given levels of the predetermined variables, and to determine the allocation of Pacific Coast Bartletts which would maximize sales revenue to growers. The model should be both a useful tool for policymakers and of practical value to decision makers in the pear industry.

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Table 4. Example Forecast of Pear Prices and Quantities for 1978

	Units	Forecast[a]	Actual[b]
Pacific Coast Bartlett pears			
Processed quantity	tons/million	1.82	1.72
Fresh quantity	tons/million	.34	.44
Processed price	\$/ton	196.29	194.00
Fresh price	\$/ton	278.00	275.00
Other West Coast pears			
All price	\$/ton	225.00	233.00
Other U.S. pears			
All prices	\$/ton	231.00	231.02

[a] Based on estimated equations for 1949–77 period.
[b] USDA, ESCS. *Noncitrus Fruits and Nuts, Midyear Supplement, Production, Use and Value.* Washington, D.C., July 1979.

References

Edwards, J. A. "An Analysis of Bartlett Pear Prices." *J. Farm Econ.* 47(1965):1278–87.

Feldstein, M. S. "The Error of Forecast in Econometric Models When the Forecast Period Exogenous Variables Are Stochastic." *Econometrica* 39(1971):55–60.

Hoos, S., and G. M. Kuznets. *Pacific Coast Canned Fruits F.O.B. Price Relationships, 1970–71.* University of California Agr. Exp. Sta. Giannini Foundation Res. Rep. 315, July 1971.

Kourouklis, S. D. "An Analysis of The Intraseasonal Demand for Bartlett Pears." Ph.D. thesis, Oregon State University, 1970.

Masud, S. M., A. D. O'Rourke, and A. H. Harrington. *Demand and Optimum Allocation for Pacific Coast Bartlett Pears.* College of Agr. Res. Ctr. Bull. 866, Washington State University, 1978.

Pubols, B. "Factors Affecting Prices of Pears." *Agr. Econ. Res.* 6(1959):16–22.

Ricks, D. J., and J. A. Edwards. Long-run Projections of Bartlett Pear Prices and Production. Oregon State University Agr. Exp. Sta. Tech. Bull. 91, 1966.

U.S. Department of Agriculture. *Agricultural Outlook.* Washington, D.C., miscellaneous issues.

U.S. Department of Agriculture. *Marketing and Transportation Situation.* Washington, D.C.., miscellaneous issues.

The Impact of Women's Time Allocation on Expenditure for Meals Away from Home and Prepared Foods

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Increased attention has been devoted in recent years to the allocation of women's time between market production, household production, and leisure. This allocation of time should have direct consequences for food preparation and consumption, because food preparation accounts for much of the time spent in household production. Despite changing sex roles, women still make most of the food-related decisions and perform much of the food selection and preparation activities. Therefore, a household's expenditure on ready-prepared foods and meals consumed away from home, as requiring the least amount of homemaker's time, should be inversely related to the amount of a woman's time allocated to household production and to those factors affecting such allocation.

The purpose of this article is to test the hypotheses advanced by Gronau, who extended Becker's time-allocation analysis to a woman's household labor time versus leisure time versus market labor time. These hypotheses are:

(*a*) If an employed woman's wage rate increases or an unemployed woman's nonwage income (including a husband's income) increases, the time that woman spends on household production will decrease.

(*b*) As children grow older, the real wage of the mother in terms of market substitutes increases (older children require less parenting time), which implies that household production time decreases and market time increases. Employed mothers substitute between market and leisure time, rather than market and household time.

(*c*) A woman's time spent on household production bears a negative relationship to the level of her education.

(*d*) Among employed women, the woman's age positively affects time spent in household production and leisure and negatively affects time in the market; among unemployed women, age negatively affects time spent in household production.

From Gronau's analysis, one would predict that family income, college education (of the woman), and age of children bear a positive relationship to expenditure on prepared foods and meals away from home. As only about a third of U.S. households contain wives employed outside the home, age and prepared foods should be positively related. The case for meals away from home is not entirely analogous, because this form of food consumption more nearly reflects changing lifestyles and values, which the younger women should adopt more readily. One would expect employed wives to spend less time on food preparation and therefore more money on prepared foods and meals away from home than unemployed wives.

Prochaska and Schrimper tested Becker's model in relation to the number of meals consumed away from home. They constructed a variable for wage of wife, as a function of age and schooling, to measure the opportunity cost of a homemaker's time. In their model, a differential effect for this variable was permitted according to whether or not the homemaker was employed outside the home. However, they were interested primarily in whether or not the opportunity cost of time was significant for either group of homemakers. They also included the effects of family income, family composition, family size, race, region, and urban/rural/farm residence.

The present study tests Gronau's hypotheses, which distinguish between three uses of time and consider the differential effects of household characteristics on these uses. Predictions more precise than Prochaska and Schrimper's concerning food consumption as an aspect of household production are thus permitted. In particular, age and schooling of the woman are included explicitly in the present model. Following Prochaska and Schrimper, race, region, and metropolitan/urban/rural residence were added as explanatory variables. Particularly because reported data consisted of expenditures on, rather than quantities of, food, dummy locational variables were desirable as controls for geographic price variation. Prochaska and Schrimper, using quantity data, analyzed income elasticities; the use of expenditure data in the present study permits estimation of the dollar influence of the various characteristics on industry sales.

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Data

Data from the diary portions of the Bureau of Labor Statistics 1972–73 and 1973–74 Consumer Expenditure Surveys provided the 9,392 observations used in multiple regression analysis. Households excluded were those that did not report for both years, that incompletely reported income, and for whom single-valued family size, age, and education information was not given. For each dependent variable, two regression models were developed (table 1), one to test the effect of family size per se and the other to test family composition. Where family size in the one regression was significant, the other regression served to locate the source of this observed effect as well as to test the Gronau hypotheses.

Total money income of the consuming unit in the previous twelve months, family size, region, age of the woman, and racial identity were obtained directly from the BLS tapes. From the ages of children given, three variables were constructed for number of preschool children (age under 6), number of elementary school children (age 6–12), and number of high school children (age 13–18). Metropolitan areas were defined as SMSAs of 400,000-plus population; urban (outside SMSAs) and rural areas were as defined by the BLS. If the head of the household was married and there was a positive income of spouse reported, the wife was presumed to be employed outside the home and the employment dummy variable took on a value of one. The presence of a college education of the woman meant that the woman had completed at

Table 1. Effects of Socioeconomic Variables on Expenditures on Meals Away from Home (regressions 1, 2) and on Prepared Foods (regressions 3, 4)

	Meals Away		Prepared Foods	
	(1)	(2)	(3)	(4)
Intercept	8.6283**	9.0949**	1.3526**	0.0656
	(.9198)	(.9512)	(.2044)	(.2091)
Family income	0.00106**	0.0011**	0.00012**	.000088**
	(.00003)	(.00003)	(.000007)	(.000007)
Employment of wife	−0.3115	0.0646	0.2588**	−0.0849
	(.4837)	(.4885)	(.1075)	(.1074)
Family composition				
Preschool children	−2.7472**	—	0.9010**	—
	(.3567)		(.0793)	
Elementary school children	−0.7390**	—	1.0946**	—
	(.3116)		(.0692)	
High school children	−0.2976	—	1.3668**	—
	(.3416)		(.0759)	
Family size	—	−1.0734**	—	1.0677**
		(.1550)		(.0341)
College education of woman	0.5896	0.1456	−0.5985**	−0.4697**
	(.5316)	(.5306)	(.1181)	(.1166)
Age of woman	−0.1370**	−0.1196**	0.0116**	0.0068**
	(.0096)	(.0093)	(.0021)	(.0020)
Region				
New England	0.8650	0.9322	1.0637**	0.9722**
	(.6527)	(.6536)	(.1451)	(.1437)
North Central	−1.8465**	−1.9147**	0.2168	0.2247
	(.6110)	(.6116)	(.1358)	(.1344)
South	−0.0944	−0.0573	0.0026	−0.0289
	(.6191)	(.6196)	(.1376)	(.1362)
Black race	−3.8775**	−3.8107**	−1.4042**	−1.4600**
	(.6914)	(.6923)	(.1537)	(.1522)
Residence				
Metropolitan	2.9032**	2.8808**	0.1616	0.1959
	(.6610)	(.6618)	(.1469)	(.1455)
Urban	−0.6878	−0.7023	0.3625*	0.3891*
	(.8340)	(.8349)	(.1854)	(.1835)
Rural	−1.8495*	−1.6846*	−0.0408	−0.1414
	(.8003)	(.8014)	(.1779)	(.1762)
R^2	.1853	.1834	.1568	.1730

Note: Standard deviation in parentheses; * significant at the 5% level; ** significant at the 1% level.

least some college. Meals consumed away from home included breakfast, lunch and dinner, but excluded school lunches and other meals such as board plans. Prepared food included prepared flour and cake mixes, bakery products, and canned or frozen meats and dinners.

Results

As the hypotheses predict, family income has a positive effect on meals consumed away from home. Family size in the aggregate has a negative effect, probably due to the financial burden of frequent meals out. However, the coefficients on the ages of the children support Gronau's hypothesis. Families with preschool children spent significantly less on meals out than other families, and families with progressively older children spent (significantly) progressively more on meals away from home. At least two explanations exist for this: the hypothesized increase in the real wage of the mother, and relevant characteristics of small children themselves such as a smaller stomach capacity and possible behavior problems in restaurants. Since the pattern is progressive through the older age groups, however, it is likely that the real wage effect holds.

Households with older women spent significantly less on meals out than do those with younger women, probably due to differences in life styles and values. The presence of an employed wife was not significant. However, because this variable referred only to wives and 35% of the sample was unmarried, effects of employment outside the home may have been obscured by similarities between employed wives and employed unmarried women with respect to eating out. The intercorrelation of wife employment and family income ($r = .37$) also may contribute to the insignificance of the former.

Households in metropolitan areas spent significantly more than average, and those in rural areas significantly less, on meals away from home. This probably reflects availability and prices of eating establishments. Other findings included lower expenditures by blacks and by households in the North Central region. Although the R^2 were not extremely high, they were comparable to those obtained by Prochaska and Schrimper.

In the case of prepared foods, as predicted, family income, employment of wife, family size, children of all ages (but with the same graduated effect noted above), and age of the woman were all positively significant. Blacks spent significantly less on prepared foods, which was consistent with the findings on meals away from home. Urban households spent more than households elsewhere on prepared foods; perhaps metropolitan households eat out while urban households (due to lesser availability of eating establishments) solve the time allocation problem by purchasing ready-prepared foods for home consumption. The woman's college education had a surprising negative effect. It is difficult to ascertain whether this is due to statistical effects (although intercorrelations among independent variables were generally not large) or whether college-educated women in fact spend less on prepared foods than other women. As they did not spend significantly more on meals away from home, it is unlikely that the prepared-foods coefficient is related to total home food expenditure. One possible explanation is that the college-educated are more nutrition-conscious and thus would be more selective of ingredients than is possible with many prepared-food purchases. As only a limited range of variables on women's characteristics were available, data did not permit further exploration.

Conclusions

The results indicate that characteristics of women which affect the allocation of their time to household production do significantly influence their households' expenditures on foods requiring relatively little preparation time. However, the effects on prepared foods consumed at home and meals away from home differ in a few respects. The family size and metropolitan/urban/rural differences already have been noted. Younger women eat out; older women buy prepared foods for home consumption. Employed wives buy more prepared foods but not more away-from-home meals, while education appears to decrease the demand for prepared foods.

These results may have considerable importance for the restaurant, fast-food, and prepared-food industries. The restaurant and fast food industries should cater to young families without small children, while the prepared-food industries should orient themselves to the older families where the wife has returned to the labor force. Since household expenditures on these food items represent sales receipts for these industries as a whole, the coefficients reported represent the dollar influence of various characteristics of women on industry sales. In particular, as increasing numbers of women undertake employment outside the home and as family incomes rise even further, these industries should experience increased sales and take on increased importance in the national economy.

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References

Becker, Gary S. "Theory of the Allocation of Time." *Econ. J.* 75(1965):493–508.

Gronau, Reuben. "Leisure, Home Production, and

Work—The Theory of the Allocation of Time Revisited." *J. Polit. Econ.* 85(1977):1099–23.
Prochaska, Fred, and R. A. Schrimper. "Opportunity Cost of Time and Other Socioeconomic Effects on Away-from-Home Food Consumption." *Amer. J. Agr. Econ.* 55(1973):595–603.

Land Treatment of Municipal Wastewater in Small Communities

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A sizable portion of the budget in many small communities is devoted to the treatment of wastewater (more commonly called sewage). A community of 5,000 persons may spend more than $150,000 annually (adjusted to a June 1978 base) for secondary wastewater treatment using trickling filters, a low-cost alternative for this size community. If, in addition, advanced wastewater treatment (AWT) is required to remove nutrients, such as phosphorus and nitrogen, in order to meet surface water quality standards, annual costs can increase to $391,000 and $443,000, depending on whether treatment techniques such as lime addition and nitrification-denitrification are used (Young 1978). These processes can remove approximately 90% of the phosphorus and nitrogen, respectively, in municipal wastewater. As national policies to improve the quality of surface waters are implemented, increasing numbers of small communities in rural areas are being required to increase the level of treatment to include AWT. Research reported in this article shows that land treatment (LT) of municipal wastewaters can meet these increased surface water quality standards for about half the cost of the AWT alternative. Because the economies of size are dramatic for all types of small-scale wastewater treatment facilities, the per unit costs of treatment may be reduced further if food processors or other industries contribute wastewater to the system (Rossi, Young, Epp). Thus, the efforts to broaden the economic base of small, rural communities may be affected by the results reported here.

In addition to its impact on resource use and community development, there also are economic impacts on farms receiving LT. These effects, of course, vary by farming region. The optimal (cost-minimizing) crops to be grown on LT areas vary from one type of farming region to another due to climatic and crop differences as well as differences in the type and number of livestock raised. Likewise, the equitable financial arrangement between the wastewater treatment authority and the farm operator may differ between regions as the value of supplemental water and nutrients varies.[1] While additional research is needed to refine the regional differences, results of such research are reported for enterprise combinations, soils, and climate typical of much of the middle Atlantic region.

The federal government has recognized the use of LT systems in solving problems of water pollution in the 1972 and 1977 amendments to the Federal Water Pollution Control Act (P.L. 92-500 and P.L. 95-217). The 1972 amendments called for nationwide improvement of the level of wastewater treatment, provided subsidies to pay for up to 75% of construction costs, and encouraged construction of revenue-producing facilities that provide for recycling potential sewage pollutants through agricultural and silvicultural production. Further support for LT was contained in P.L. 95-217, which made receipt of a federal construction subsidy contingent upon explicit consideration of innovative and alternative treatment and provided an additional 10% construction subsidy for these techniques. An innovative or alternative system is deemed cost effective if its costs are not more than 115% of the least costly treatment alternative available.

Land treatment as a technique for achieving AWT of municipal wastewater is examined in this paper. First, the LT process is described and treatment costs are simulated for community sizes ranging from 5,000 to 250,000 persons. Then the effect of crop selection on LT systems is analyzed followed by a discussion of the impact of federal construction subsidies on LT costs.

Land Treatment Processes

Land treatment refers to the controlled discharge of partially treated sewage effluents onto land to remove contaminants from the water. The soil and/or agricultural crops or forests absorb and filter ni-

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[1] One further aspect of research on LT that is of particular interest to production economics theorists is the negative price associated with the nutrients and water as inputs to a farm business. Because alternative disposal techniques frequently cost a great deal more than application to farmland, the opportunity cost of the wastewater inputs is negative meaning that the profit-maximizing level of use is in Stage III of the production function. Research on land treatment of wastewater provides an opportunity for empirical testing and demonstration of a phenomenon that differs from conventional production theory.

trates, phosphates, organics, and other elements from the effluent. Generally, a portion of the vegetative cover is harvested to remove nutrients from the site and to provide a revenue to offset partially the treatment costs. The design and operation of LT systems are described in two reports from the U.S. Environmental Protection Agency (1975, 1977).

The three basic ways of applying wastewater to land for treatment and removal of pollutants are irrigation, overland flow, and rapid infiltration. The most common method is irrigation, using conventional irrigation techniques such as center pivot, solid set, border strip, and ridge and furrow irrigation techniques. An agricultural or silvicultural crop is usually grown in conjunction with an irrigation system. In an irrigation system, the wastewater is applied at a rate of 1 to 6 acre-inches of wastewater per week and the water is purified as it passes through the root zone of the vegetative cover. Irrigation systems remove 85% of the applied nitrogen and 80% to 99% of applied phosphorus. Overland flow refers to the application of wastewater onto an impermeable soil with a slope of 2% to 4%. The water flows down the slope with the renovation of the wastewater occurring in the upper 1 to 2 inches of soil. Approximately 70% to 90% of nitrogen and 40% to 80% of phosphorus are removed. Application rates range from 2 to 9 acre-inches per week for overland flow. The final method of land treatment of wastewater is rapid infiltration where large quantities of water (4 to 120 acre-inches per week) are applied to a highly permeable soil such as sand or gravel. Treatment efficiency is lower for this type of system. Removal rates are less than 50% for nitrogen removal and range from 60% to 95% for phosphorus removal. (This analysis concentrates on the irrigation alternative. Individuals interested in the two other methods of land application are referred to Young, 1976.)

Land treatment costs are influenced by numerous interrelated variables. Design factors which the community has some control over include: (*a*) degree of pretreatment, (*b*) effluent transmission (pumping) costs, (*c*) land costs, (*d*) annual rate at which water is applied to the site, (*e*) type of vegetative cover, and (*f*) restrictions placed on the system to prevent the spread of disease organisms. These variables may be traded off against one another in order to minimize treatment costs. For example, a community can pump its wastes further from the city to obtain less costly land. Alternatively, land requirements can be reduced by selecting a crop or vegetative cover that can be irrigated at a higher annual rate.

The community will have less control over variables influencing LT costs, such as: (*a*) rainfall, (*b*) soil type, (*c*) topography, (*d*) length of growing season, and (*e*) local citizens' attitudes toward the installation of an LT system. The community also has little control over the institutional setting in which it must operate, such as, the legal power to enter into joint wastewater authorities with other municipalities, to contract land for land application services, or to acquire title to land for wastewater irrigation sites. About the only control the community has over these factors is selection of an appropriate site and public education.

An important factor affecting the cost and performance of a land application system is the particular crop or crops which are selected for wastewater irrigation. Crop selection affects the revenue which can be generated from sales of the agricultural crop which is irrigated. Certain crops are capable of being irrigated for longer periods of time throughout the year which eliminates the need for storing the wastewater and the associated costs of storage and applying the stored wastewater to the land at a later date. Thus, the longer the irrigation season, the lower are the costs of wastewater irrigation. Finally, the amount of wastewater that can be applied within a specified time period, such as one week, to a crop also affects the costs of the land application system. The more wastewater that can be applied while maintaining the crop yield and renovative capacity of the land application system, the lower the cost will be. Certain crops, such as grasses, tend to remove nutrients while accepting higher quantities of wastewater.

A wide variety of cropping activities has been suggested or utilized for land application systems. Crops include forages such as reed canarygrass, bermuda grass, and alfalfa hay; grains such as corn, barley, and sorghum; cotton; and silvicultural crops such as hardwood forests and pine forests. Additional experiments have been performed with land application on uncultivated fields or natural vegetation. In this analysis, we limit the crops examined to those for which we have experimental results showing the effect on crop yield and performance of wastewater irrigation. Thus, our results apply to data from experiments at Pennsylvania State University as reported by Kardos et al. This is the only information of which the authors are aware that pertains to crop yields and renovative capacities for wastewater application performed over a long period of time (fifteen years).

The cost effectiveness of LT relative to alternative AWT options has been analyzed using engineering simulation models and statistical analyses of existing facilities. Pound, Crites, and Smith compared simulated AWT costs with LT costs for three sets of assumptions (favorable, mildly favorable, and unfavorable). Alternatively, Young (1978) identifies conditions which influence the relative cost effectiveness of LT. Williams, Conner, and Libby compared six small operating LT systems with four conventional treatment systems. Young and Carlson, using regression analysis, compared twenty-one irrigation systems with thirty-one AWT systems. Each of these studies reached a similar conclusion. Land treatment is cost effective for small facilities—those capable of treating less than five to ten million gallons per day (mgd) of wastewater.

Method of Analysis

The cost of land application of wastewater (CLAW) simulation model is used to study the design of land application systems in the following analysis. The CLAW model is a computer simulation model which can be used to design land application systems capable of treating from 0.1 mgd to 100 mgd of wastewater per day using six alternative application techniques. The application techniques include solid-set irrigation, center pivot irrigation, border strip irrigation, ridge and furrow irrigation, overland flow, and infiltration basins. The model as described by Young (1976) has six basic steps: preapplication treatment, effluent transmission, wastewater storage, application of the wastewater, cropping, and recovery of the renovated wastewater if desired. Simulation was selected as the mode of analysis due to the extreme nonlinearities associated with land application systems which will be evident in the data presented in the following section. By altering the data read into the model, the results can be generalized to a wide variety of situations.

Land Treatment Costs

Even though land treatment is a recycling process and produces a saleable by-product in many instances, it is still a costly undertaking. Cost estimates for solid-set (SSI) and center pivot (CPI) irrigation of reed canarygrass are illustrated in table 1. Based on the experimental results at Pennsylvania State University (Kardos et al.), the cost estimates assume that canarygrass is irrigated year-round. The estimates apply to facility sizes ranging from 0.5- to 25-mgd treatment capacity. The cost estimates range from $175,200 per year for the 0.5-mgd CPI system to $3,614,500 per year for the 25-mgd SSI system. Examination of the cost estimates in table 1 reveals that there are significant economies of size on a per mgd treatment basis. Costs fall from $372,000 per mgd for a 0.5-mgd SSI facility to $145,000 per mgd for the 25-mgd facility. Most of the advantages to increasing facility size are reached when the design capacity exceeds the 5- to 10-mgd range.

For explanatory purposes, the total cost estimates in table 1 are divided into capital, operating, and net crop revenue. The capital and operating cost estimates refer to the operation of the irrigation system, while the net crop revenue estimates apply to the net profit (or loss) from the cropping enterprise. Capital costs make up the largest proportion of the total cost estimates for both types of irrigation facilities. For SSI systems capital costs comprise 75% to 76% of annual total costs, while capital costs comprise 69% to 73% of the annual total costs for CPI systems. Conversely, the operating costs for the CPI systems are slightly higher than those for the SSI systems.

Table 1. Costs (1978) of Year-Round Wastewater Irrigation of Reed Canarygrass

Facility Size (mgd)	Solid-Set Irrigation		Center Pivot Irrigation	
	Annual	Per mgd	Annual	Per mgd
	Total Costs ($)[a]			
0.5	186,300	372,000	175,200	350,400
1.0	274,000	274,000	249,700	249,700
5.0	882,500	176,500	750,800	150,100
10.0	1,588,000	158,800	1,315,400	131,500
25.0	3,614,500	145,000	2,906,400	116,300
	Capital Costs at 6% for Twenty Years ($)			
0.5	141,600	283,200	127,500	255,000
1.0	206,200	206,200	177,700	177,700
5.0	665,700	133,100	519,500	103,900
10.0	1,201,400	120,100	905,600	90,600
25.0	2,752,800	110,100	2,002,100	80,200
	Operating Costs ($)			
0.5	50,200	100,400	53,200	106,400
1.0	78,800	78,800	83,000	83,000
5.0	272,100	54,400	286,500	57,300
10.0	497,100	49,700	520,400	52,000
25.0	1,137,900	45,500	1,180,500	47,200
	Net Crop Revenue ($)			
0.5	5,500	11,100	5,500	11,100
1.0	11,100	11,100	11,000	11,100
5.0	55,300	11,100	55,300	11,100
10.0	110,500	11,100	110,500	11,100
25.0	276,300	11,100	276,300	11,100

[a] Total costs are the sum of capital and operating costs less net crop revenue.

To understand better the impact of crop selection on the cost of land application facilities, the profits and loss from the cropping enterprise were separated from the irrigation costs. In this example, reed canarygrass is irrigated year-round. Based on demonstrated results reported in Kardos et al., it is assumed that the reed canarygrass can be irrigated throughout the year and still maintain a high degree of renovation of the wastewater which is percolating through the soil profile. Two important features of the profit from irrigating reed canarygrass should be noted. First, it is assumed that there are no economies or diseconomies of size associated with the cropping operation. Second, it is assumed that the reed canarygrass is harvested as silage and has a value of $15 per ton. This value was based on nutrient content and on experimental feeding of reed canarygrass to cattle at Pennsylvania State University (Bradley).

Alternative Cropping Patterns

Other crops for which data exist on response to wastewater irrigation include alfalfa, corn, and several types of forests and other uncultivated areas. The annual total cost estimates for four crops at three application rates and various lengths of irrigation season are presented in table 2 for 1-mgd SSI systems. The SSI system was chosen for this analysis because it is more frequently used in operating systems even though our analysis shows CPI systems to be less expensive. Similar results will occur if CPI systems are substituted for SSI systems. Comparison of the results in this table will provide generalizations for the impact of wastewater irrigation in various regions of the country. It should be noted that the price for which crops may be sold and the renovative capacity of the predominant soil types will vary depending upon local conditions. Thus, the results are suggestive and not conclusive.

Table 2. Annual Total Cost Estimates (1978) for Alternative Cropping Patterns for a 1.0 mgd Solid-Set Irrigation System

Crop	Weeks of Irrigation	Application Rate (inches/week) 1	2	3
		---------	($)	---------
Reed canarygrass	52	347,300	274,000	249,100
	48	385,900	306,200	279,400
	40	466,300	369,700	338,000
	32	560,700	438,500	399,200
Alfalfa	40	429,800	343,800	320,800
	36	470,400	374,300	349,000
	32	514,900	406,200	377,700
Corn	40	445,000	357,800	340,000
	36	487,400	389,800	370,300
	32	543,000	423,700	401,700
	28	587,100	460,900	435,300
Forest	52	412,200	307,500	272,100
	48	456,100	342,300	304,200
	40	550,600	412,400	367,400
	32	666,200	491,300	435,300

The general impact on the annual total cost estimates of varying the amount of wastewater which is applied to a particular area of land is examined first. The amount of wastewater applied to a particular area is determined by two factors: (*a*) the weekly rate at which wastewater is applied and (*b*) the number of weeks of wastewater irrigation. The effect of varying these two variables is illustrated in table 2. For example, for reed canarygrass increasing the application rate from one to two inches a week with year-round (fifty-two weeks) wastewater irrigation reduces annual total costs from $347,300 to $274,000. Further increasing the application rate to three inches per week decreases the annual total costs to $249,100. Increasing the rate at which the wastewater is applied to the land effectively reduces the area which must be irrigated. Acreage requirements fall from approximately 301 to 159 to 111 acres for the application rates examined—one, two, and three inches per week, respectively. The longer the irrigation season, the lower the costs are also. For example, for the two-inch per week application rate with reed canarygrass, if the irrigation season is thirty-two weeks per year, annual total costs are $438,500, while for an irrigation season of forty-two weeks per year the annual total cost estimate is $369,700, and if the reed canarygrass can be irrigated year-round, annual total costs fall to $274,000. Thus, it may be concluded that the more wastewater which can be applied to a particular area of land without exceeding the capacity of the soil-crop combination to remove nutrients from the water, the lower annual total costs will be. Increasing the length of the irrigation season reduces effective land requirements from 294 acres for a thirty-two-week irrigation season to 159 acres for the year-round irrigation season.

Irrigation of crops such as alfalfa and corn cannot be carried out year-round and still maintain adequate renovation of the wastewater (Kardos et al.). If the irrigation season is restricted because of climatic constraints or other conditions associated with the winter season, the irrigation of corn and alfalfa become more cost-effective than irrigation of reed canarygrass (table 2). When irrigated with comparable quantities of water, say two inches per week for thirty-two weeks per year, alfalfa and corn are less costly than irrigation of reed canarygrass ($406,200, $423,700, and $438,500, respectively). In many areas reed canarygrass may be capable of being irrigated for a longer period of time than either alfalfa or corn as shown by Bradley. If, for example, reed canarygrass can be irrigated for forty weeks per year while corn and/or alfalfa can only be irrigated for thirty-two weeks per year, the reed canarygrass remains the least-cost alternative. If, on the other hand, alfalfa and corn can be irrigated for thirty-six weeks per year, the relative cost

advantage for irrigation of reed canarygrass for forty weeks annually decreases.

A fourth "crop" which may be irrigated with wastewater is forest land. Forests may be irrigated for longer seasons because of the coverage of the trees which permits infiltration of the wastewater in the soil during colder times. A disadvantage of forests is that a crop is seldom harvested because of the long time required for forests to mature. Thus, fewer nutrients are harvested from the land application site, which may lead to a lower performance in terms of nutrient removal. Revenues from the more frequent crop sales are higher for agricultural crops than for forests. Also, forest irrigation is more costly than irrigation of field crops because SSI must be used and the irrigation risers must be closer together to achieve an adequate distribution of the wastewater over the site (Pound, Crites, Griffès). If forests can be irrigated for longer periods of time, their cost effectiveness increases. An additional benefit to forest irrigation not quantified into the cost estimates is that forest irrigation may be more acceptable to the public than crop irrigation. Irrigation of forests is less visible and therefore less likely to lead to public opposition. One alternative for forest irrigation not examined in this analysis is the irrigation of fast-growing pulpwoods that can be harvested on four to five-year rotations. It is likely that this type of system would increase the renovative ability of a forest and also provide additional revenue to offset the costs of the irrigation operation.

A critical assumption underlying the analysis thus far is the value of reed canarygrass silage, assumed to be $15 per ton. This may not be a representative value for two reasons: (*a*) regional variations in silage values and (*b*) the lack of actual market price data underlying the estimate. In this analysis, the value of reed canarygrass silage is computed from its nutrient composition compared to corn and soybean oil meal and the price of the reference feeds (Bradley, pp. 92–93). Reducing the value of reed canarygrass silage decreases the relative cost effectiveness of the reed canarygrass option. For example, at $7.50 per ton for reed canarygrass silage (a 50% decrease) irrigation of reed canarygrass for forty weeks per year with a two-inch per week application rate costs $386,900. This value is about the same as irrigation of corn and alfalfa for thirty-six weeks per year at the two-inch per week application rate.

Minimizing Local Costs with a Construction Subsidy

Grants are available from the U.S. Environmental Protection Agency to pay for up to 75% of initial construction costs for conventional wastewater treatment facilities and up to 85% of initial construction costs for innovative and alternative treatment operations. Under the provisions of P.L. 95-217, land treatment is specifically defined as an alternative treatment technology. With a federal construction subsidy, a community may decide that it would be best to minimize local costs of LT as opposed to minimizing the total costs (local plus federal) of LT. If it does this, the community will discover quickly that irrigation of crops with shorter irrigation seasons, such as corn and alfalfa, may be more cost-effective (table 3). For example, with an 85% subsidy applied to eligible items and a two-inch per week application rate, irrigation of corn and alfalfa for thirty-two weeks per year compares favorably with irrigation of reed canarygrass for forty weeks per year. In fact, irrigation of alfalfa for thirty-two weeks per year is less costly than irrigation of reed canarygrass for forty-eight weeks per year. The subsidies provide an incentive for communities to select systems which are not necessarily the least-cost alternative from the viewpoint of society.

With a construction subsidy, maximizing the amount of wastewater applied is not always associated with minimization of local costs. When alfalfa and corn are irrigated with an 85% subsidy, local costs are lower with a two-inch per week application rate than for a three-inch application rate. This occurs because the additional crop revenue from irrigating more land offsets the additional unsubsidized costs for irrigation and land to the local community. With corn, an increase of four weeks in the length of the irrigation season for the one- and three-inch per week application rates does not reduce local costs sufficiently to be less costly than the two-inch per week alternative. For example, irrigating corn for thirty-two weeks per year at the two-inch per week application rate is less costly than irrigating corn at one or three inches per week

Table 3. Annual Local Cost Estimates (1978) for Alternative Cropping Patterns for a 1.0 mgd Solid-Set Irrigation System with an 85% Capital Subsidy

Crop	Weeks of Irrigation	Application Rate (inches/week) 1	2	3
		($)		
Reed canarygrass	52	116,400	103,300	98,600
	48	125,000	110,800	105,700
	40	141,900	124,700	118,900
	32	161,500	139,700	132,500
Alfalfa	40	105,300	98,900	101,700
	36	110,700	103,300	106,500
	32	115,800	107,400	111,000
Corn	40	120,600	112,800	120,900
	36	127,600	118,800	127,900
	32	134,900	124,800	134,900
	28	138,000	129,800	142,100
Forest	52	153,900	122,800	112,100
	48	165,500	131,900	120,200
	40	190,300	149,700	136,000
	32	221,800	170,400	153,600

for thirty-six weeks per year. Again, this phenomenon is caused by the additional crop revenue associated with irrigation at the two-inch application rate as opposed to the unsubsidized costs associated with the other irrigation alternatives.

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References

Bradley, E. B. "Optimal Utilization of Land in Municipal Wastewater Land Treatment Systems: An Economic Analysis." Ph.D. thesis, Pennsylvania State University, 1978.

Kardos, L. T., et al. *Renovation of Secondary Effluent for Reuse as a Water Resource.* Washington, D.C.: U.S. Environmental Protection Agency, EPA-660/2-74-016, 1974.

Pound, C. E., R. W. Crites, and D. A. Griffes. *Costs of Wastewater Treatment by Land Application.* Washington, D.C.: U.S. Environmental Protection Agency, EPA-430/9-75-003, 1975.

Pound, C. E., R. W. Crites, and R. G. Smith. *Cost Effective Comparison of Land Application and Advanced Wastewater Treatment.* Washington, D.C.: U.S. Environmental Protection Agency, EPA-430/9-75-016, 1975.

Rossi, D., C. E. Young, and D. J. Epp. "The Cost Impact of Joint Treatment of Domestic and Poultry Processing Wastewaters." *Land Econ.* 55(1979):444–59.

U.S. Environmental Protection Agency. *Evaluation of Land Application Systems.* Washington, D.C.: EPA-430/9-75-001, 1975.

U.S. Environmental Protection Agency, U.S. Army Corps of Engineers, and U.S. Department of Agriculture. *Process Design Manual for Land Treatment of Municipal Wastewater.* Washington, D.C.: EPA 625/1-77-008, 1977.

Williams, J. R., L. J. Conner, and L. W. Libby. *Case Studies and Comparative Cost Analysis of Land and Conventional Treatment of Wastewater by Small Communities in Michigan.* Dep. Agr. Econ. Rep. No. 329, Michigan State University, 1977.

Young, C. E. *The Cost of Land Application of Wastewater: A Simulation Analysis.* Washington, D.C.: USDA ERS Tech. Bull. 1555, 1976.

———. *Land Application of Wastewater: A Cost Analysis.* Washington, D.C.: USDA ESCS Tech. Bull. 1594, 1978.

Young, C. E., and G. A. Carlson. "Land Treatment versus Conventional Advanced Treatment of Municipal Wastewater." *J. Water Pollution Control Fed.* 47(1975):2565–73.

Cost of Production: A Defensible Basis for Agricultural Price Supports?

E. C. Pasour, Jr.

Price supports have been used to increase the price of various agricultural commodities in the United States since the 1930s. Although price supports were conceived as a way of increasing farm income relative to nonfarm income, the level at which prices should be supported has been a key issue. Various farm organizations, economists, and politicians have maintained since the early 1920s that prices of farm commodities should be maintained at levels sufficient to cover production costs (Luttrell). The parity price concept was, in itself, an attempt to relate the support price to production costs through the prices-paid index. The shortcomings of the parity concept as a basis for setting agricultural prices are well known (Tomek and Robinson, p. 207).

Recently, cost of production has been proposed as a substitute for parity in measuring the equity of returns to agriculture. This concept is embraced in the Food and Agriculture Act of 1977 as a primary guide in determining support or target price levels. Producers and politicians largely have ignored a long tradition of attacks and debunking of cost of production as a welfare criterion. Economists have pointed out that there is no single cost of production number because cost varies (among other reasons) according to length of run and quantity of production (Stovall and Hoover). However, there appears to be no consensus even among economists that cost of production as a guide to setting support or target prices is, as recently stated, an "economically indefensible" concept (Johnson, p. 789). In a recent workshop devoted to evaluating Economics, Statistics, and Cooperatives Service (ESCS) cost-of-production work, for example, the focus was on "the difficulties of arriving at reasonable cost of production estimates" (p. i). This paper focuses on theoretical and measurement problems inherent in attempts to base price supports on cost and it questions whether "reasonable" cost-of-production estimates can be made for this purpose.

The analysis accepts the findings of other studies that government price and income support programs are capitalized into the price of land, rights to produce, and other assets (Hedrick; Seagraves). It does not discuss the rationale for income support of the farm sector or the effect of price supports on the stability of commodity prices; it is instead addressed to problems inherent in attempts to base support prices on production costs. The problems of using market prices of resources to estimate production costs when resources are specialized are explored both at the industry and firm levels. Measurement problems inherent in the concept of opportunity costs also are stressed. The analysis concludes that the use of cost data as a basis for agricultural price supports is "economically indefensible" regardless of whether cost estimates are made at the firm or industry level.

Specialized Resources

The use of cost of production as a basis for setting support prices presumes that opportunity cost is an objective concept which can, at least in principle, be measured by outside observers.[1] The use of market data has been suggested as a way of determining the cost of land and other inputs (Sharples and Krenz, p. 64). However, an intractable problem arises when one attempts to determine cost of production from market data when production involves specialized resources.

In the treatment of cost, economic theory texts generally assume a world of unspecialized resources (Leftwich, Ch. 9). In this model, cost can be defined independently of product demand, so that a change in demand has no effect on production costs. In the real world, however, land, labor, productive facilities, and entrepreneurship are specialized to the firm in the sense that it is impossible to duplicate precisely the resources of any particular firm (Friedman, p. 147).[2] Friedman points out the problem posed by specialized resources to conventional cost (and, hence, supply) analysis.

> The existence of specialized resources . . . makes it impossible to define the average cost of a particular firm for different hypothetical outputs independently of demand. . . . Take the copper mine of the preceding paragraph: its cost curve cannot be computed

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[1] In this and the following section of this paper, "cost" is taken to be equivalent to the market outlays of conventional static equilibrium.

[2] A specialized input at the industry level is sometimes referred to as a "specific input," i.e., one whose supply curve is less than perfectly elastic.

> without knowledge of the royalty or rent that must be paid to owners of the mine, if the firm does not itself own it, or imputed as royalty or rent, if the firm does. But the royalty is clearly dependent on the price at which copper sells on the market and is determined in such a way as to make average cost tend to equal price . . . . The equality of price to average cost . . . is forced on the firm by the operation of the capital market or the market determining rents for specialized resources. (Friedman, p. 147)

If firm A owns a superior input (e.g., land which is unusually productive), the return to the specialized resource is capitalized into higher land costs. Competition bids up the price so that firm A faces costs similar to those of firm B and other firms with less productive resources when the returns to specialized resources are included in costs.

Under these conditions, average cost of production cannot be defined independently of demand conditions; an increase in product demand which increases expected product price increases returns to specialized resources and, consequently, costs. The larger the increase in expected product price, the higher the returns to specialized factors. Competition results in a capitalization of the returns to the specialized factors into higher costs so that higher rates of return on investment to firms with the more productive factors are not expected to persist over time.

Similarly, when production of an agricultural product is restricted as a means of supporting price above the market level, the right to produce (tobacco poundage quota, peanut allotment, milk base, etc.) acquires a value. The value of the right to produce, as in the case of other resources not perfectly elastic in supply, cannot be determined independently of product demand. Thus, an increase in product price will increase the expected value of the right to produce and, consequently, the expected cost of production.

When expected product price is supported above the current market level, increases in product price will be capitalized into prices of production rights, land, and other specialized inputs through competitive market forces so that expected product outlays tend to rise to meet expected returns. Consequently, attempts to set price supports on the basis of production outlays are futile in real world production because the higher the level at which prices are supported above the market level, the higher will be the required production outlay. As long as some inputs are less than perfectly elastic in supply, there is no way to avoid this dog-chasing-its-tail ratchet effect in which an increase in the level of price support brings about an increase in production outlays.

The preceding analysis also casts light on land cost. Some economists have held that land costs should be excluded from production costs which are to be used as a basis for setting support prices. The costs of land, however, are a part of the individual producer's opportunity cost. Any decision to exclude portions of cost in arriving at "production cost" must be arbitrary. There is no more reason to exclude the cost of land than to exclude the cost of a production right (e.g., allotment cost). In each case, the outlays represents a bona fide cost from the standpoint of the individual producer.

Implications for Cost Measurement

Consider the procedure for estimating cost commonly used in constructing enterprise budgets in which the market price of each resource used in producing a product is taken as an estimate of that input's cost. The cost of producing peanuts, for example, is determined by adding together the market value (or estimates thereof) of land, allotment value, labor, fertilizer, pesticides, machinery, and other inputs required to produce an acre of peanuts. Market outlays are equal to opportunity costs, however, only when resources are unspecialized under highly restrictive equilibrium conditions (Vaughn, p. 714).[3]

When resources are specialized and producers are motivated only by pecuniary considerations, competition in the capital market forces average cost toward an equality with price: hence, average costs for different firms will tend to be equal provided they are all properly computed so as to include the quasi-rents (returns to specialized resources). Under these conditions, a difference between expected product price and the sum of market input prices may be taken as an indication of the efficiency of the capital market in revaluing assets (Friedman, p. 148). Thus, the use of market input prices to estimate production cost is theoretically unsound in a world of specialized resources including production rights and land.

Although market prices of fertilizer, pesticides, and other nonspecialized inputs generally are used in enterprise budgets, the concept of market price often has little meaning in the case of operator labor, management, land, and capital facilities.[4] The characteristics and value of these specialized inputs is acknowledged to vary from firm to firm. Consequently, a great deal of effort has been devoted to production cost analyses at the firm level.

[3] "If the whole economy is not operating at full competitive equilibrium, profits-losses may occur and, hence, observed outlays cannot be taken to reflect foregone opportunities of the actual decision-makers in any general setting. . . . . It is important to note that quasi-rents cannot exist in the competitive equilibrium required in this model. . . . The reason is that the presence of 'quasi-rents,' the individual or the firm has available more than one loss-avoiding alternative course of action. . . . even in full equilibrium resource-service prices reflect costs only if nonpecuniary advantages or disadvantages are absent from the choices of resource-supply agents" (Buchanan 1969a, pp. 49–75, and 86).

[4] Coase (pp. 110–13) cautions, however, that even in the case of purchased inputs the price paid by the firm is unlikely to equal their opportunity cost.

Estimating Cost at Firm Level

Estimation of cost at the firm level, however, is no panacea. There are at least three kinds of problems. The first two kinds of problems pertain to the procedure of equating opportunity cost with market outlays. First, the problem posed by specialized resources discussed above is not obviated by estimating cost at the firm level. Typically, cost studies based on accounting data reveal wide differences in average cost from firm to firm. Data obtained through the North Carolina Dairy Farm Business Records Program, for example, show that the net cost of producing milk by the enrolled dairymen was twice as high for the upper 10% when compared with the lower 10% of farms ranked according to cost of production (Wells and Sutter). The variation in accounting costs between firms, however, need not be caused by differences in *ex ante* costs but may represent differences in the accuracy of accounting data or in the efficiency of the capital market in revaluing resources. Competition in the capital market will force expected outlays at the firm level toward expected product price in the manner described above.

Second, quasi-rents cannot exist in competitive equilibrium if market input prices are to represent opportunity costs. If there are no rents and nonpecuniary considerations do not enter the choices of resource supplying agents, the opportunity costs are the objectively measurable outlays of competitive equilibrium. If such rents exist, however, "there can be no presumption that anticipated outlay measures subjective opportunity costs, those that must influence actual choice behavior" (Buchanan 1969a, p. 75). Thus, the existence of specialized resources (and the consequent quasi-rents) destroys the link between market prices and choice-influencing costs.

Third, and closely related, estimation problems arise because of the subjective nature of opportunity cost. The opportunity cost of any decision is the value of sacrificed alternatives as a result of the action taken. Thus, cost as it influences entrepreneurial choice is the decision maker's own assessment of opportunities foregone. Furthermore, because the opportunities foregone are not actually experienced, the assessment of the rejected course of action depends upon the decision maker's anticipations of future conditions. In empirical work, the expected value of the sacrificed alternative tends to be ignored in estimating cost and is replaced by factor prices. Cost defined as resource outlay, however, has no necessary connection with the value of the rejected course of action or, consequently, the entrepreneur's act of choice (Thirlby).

Note how the concept of cost implicit in the following passage is unrelated to the act of choice and inconsistent with the opportunity cost concept.

> Costs per unit vary among farms for many reasons. First, a farmer's actual production usually does not equal his expected production . . . . For example, the 1974 corn yield of 74.3 bushels per acre was unusually low. With normal weather conditions, the yield would have been 20–25 percent higher, and costs per bushel, much lower. If farmers had obtained 1973 corn yields in 1974, their costs would have been reduced over 20 percent per bushel. (Sharples and Krenz, p. 65)

Cost in the choice-influencing opportunity cost sense, however, concerns sacrificed alternatives at the moment of choice. Whether the yield is eventually higher or lower than anticipated has no relevance to opportunity cost. The opportunity cost is not affected unless the decision maker's estimate of the best alternative is affected at the time the decision was made (Alchian, p. 303).

The following example demonstrates why cost as it influences entrepreneurial choice varies widely from producer to producer and illustrates the problems faced by the outside observer in measuring opportunity cost. Consider the cost of land in the production of corn. The cost of similar land in corn may be quite different for Jones relative to his neighbor Smith. The opportunity cost of land used to produce corn is the value of that land in its best alternative use (say soybeans). Costs occur in the planning stage and any planning acitivity must deal with an uncertain future. Consequently, the expected value of land used to produce soybeans hinges on expected soybean outlays, prices, and yields. Jones, for example, may anticipate a return to land of $25 per acre when using the land in soybeans. Smith, on the other hand, being more optimistic about future soybean yields and prices, may anticipate a return of $40 per acre to land in soybeans. Under these anticipated conditions, the opportunity cost per acre of land to produce corn is $25 for Jones and $40 for Smith. These are the relevant costs for Jones and Smith to impute to land in producing corn when the land is owned; these are also the relevant costs even though both farmers may have paid the same market or contract rental price for land. Long-term contracts at a fixed price do not prevent fluctuations in opportunity cost.

Uncertainty also complicates the estimation of overhead costs. The relevant depreciation (including obsolescence) cost hinges on the unknown future and, consequently, expectations are crucial in the estimation of overhead costs of machinery and other capital.[5] Depreciation and interest cost estimates by outside observers must be based on the historical "cost" records of the business firm or on the observer's expectations of future conditions. Because the relevant cost estimates are necessarily expectations rooted in uncertainty, overhead cost estimates by outside observers may bear little rela-

[5] "In no sense can costs during any period be said to depend solely on prices during that period. . . in fact, almost every real world decision concerning how to produce depends at least in part on the views held about the future" (Hayek, p. 198).

tionship to the opportunity costs which motivate the entrepreneur (Shackle 1972, 1974).

Finally, subjectivity enters cost estimates when Jones places a value on his time. The appropriate cost of time for Jones in producing corn is the opportunity cost of his time. This value of the best sacrificed alternatives as it affects choice, however, is unique depending upon the decision makers subjective evaluation, and is not observable to the independent analyst.[6]

These examples demonstrate that the cost of land, labor, and capital inputs (as they influence entrepreneurial choice) are inherently subjective under real world conditions and not observable by outside parties (Pasour). A recognition of this phenomenon explains why Jones may rationally choose to plant corn and Smith to plant soybeans even though a conventional enterprise budget of costs and returns of corn production might show the same cost for each producer.

How can there be ambiguity over the seemingly simple opportunity cost concept? At least some of the confusion follows from the usual textbook treatment of cost. Major emphasis is placed on profit maximization when costs and returns are assumed given or known to economic actors and observers (Kirzner 1973, 1978). Under real world conditions of uncertainty, however, these data are not given and a key role of the entrepreneur is to assess the cost of alternative courses of action. Moreover, there is no reason to expect a cost estimate by an entrepreneur to correspond to that of the economist because the data upon which choices are based are distinct from data that can be objectively measured by external observers (Buchanan 1969b, p. 64).

This paper has discussed problems related to defining and measuring cost used as a basis for price supports. The cost of producing a commodity is meaningful only in a static equilibrium model and, even then, cost cannot be defined independently of demand when resources are specialized. Under real world conditions, opportunity costs are subjective and vary widely between producers. The preceding analysis does not deny that government can vary output levels by price setting. What is challenged is the contention that such an approach involves the basing of price supports on cost. In view of the problems raised above, attempts to define and estimate "reasonable cost estimates" as a basis for agricultural price supports appear to be foredoomed.

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[6] Even in full market equilibrium where all resources are unspecialized, the choice influencing cost of the resource units is not observable in money prices paid for resources if nonpecuniary considerations are present in decisions made by suppliers of labor (or other resources) (Buchanan 1969a, p. 86–87).

References

Alchian, A. A. "Cost." *Economic Forces at Work: Selected Works by Armen A. Alchian*, pp. 301–33. Indianapolis, Ind.: Liberty Press, 1977.

Buchanan, J. M. *Cost and Choice*. Chicago: Markham Publishing Co. 1969a.

———. "Is Economics the Science of Choice?" *Roads to Freedom—Essays in Honour of Friedrich A. von Hayek*, ed. E. Streissler. New York: Augustus M. Kelley, 1969b.

Coase, R. H. "Business Organization and the Accountant." *L.S.E. Essays on Cost*, ed. J. M. Buchanan and G. F. Thirlby, pp. 95–132. London: Weidenfeld and Nicolson, 1973.

Friedman, Milton. *Price Theory*. Chicago: Aldine Publishing Co., 1976.

Hayek, F. A. *Individualism and Economic Order*. Chicago: University of Chicago Press, 1948.

Hedrick, J. L. "The Effects of the Price Support Program for Peanuts on the Sale Value of Farms." *J. Farm Econ.* 44(1962):1749–53.

Johnson, D. Gale. "National Agricultural Policies and Market Relations." *Amer. J. Agr. Econ.* 60(1978): 789–92.

Kirzner, I. M. "Alertness, Luck and Enterpreneurial Profit." Paper presented at meeting of American Economic Association, Chicago, 31 Aug. 1978.

———. *Competition and Entrepreneurship*. Chicago: University of Chicago Press, 1973.

Leftwich, R. H. *The Price System and Resource Allocation*, 6th ed. Hinsdale, Ill.: Dryden Press, 1976.

Luttrell, Clifton B. "Farm Price Supports at Cost of Production." *Review*. Federal Reserve Bank of St. Louis, no. 12 (1977), pp. 2–7.

Pasour, E. C., Jr. "Cost and Choice—Austrian vs. Conventional Views." *J. Lib. Stud.* 2(1978):327–36.

Seagraves, J. A. "Capitalized Values of Tobacco Allotments and the Rate of Return to Allotment Owners." *Amer. J. Agr. Econ.* 51(1969):320–34.

Shackle, G. L. S. "Decision: The Human Predicament." *Annals of the American Academy of Political and Social Science* 412(1974):1–10.

———. *Epistemics and Economics: A Critique of Economic Doctrines*. London: Cambridge University Press, 1972.

Sharples, J. A., and R. Krenz. "Cost of Production: A Replacement for Parity?" *Agricultural Food Policy Review* pp. 62–68. Washington, D.C.: USDA ERS AFPR-1 1967.

Stovall, John G., and Dale Hoover. "An Overview of the Cost of Production—Uses, Concepts, Problems, and Issues." *Estimating Agricultural Costs of Production—Workshop Proceedings*, pp. 3–11. Washington, D.C.: USDA ESCS-56, 1979.

Thirlby, G. F. "Economists' Cost Rules and Equilibrium Theory." *L.S.E. Essays on Cost*, ed. J. M. Buchanan and G. F. Thirlby, pp. 273–87. London: Weidenfeld and Nicolson, 1973.

Tomek, W. G., and K. L. Robinson. *Agricultural Product Price*. Ithaca, N.Y.: Cornell University Press, 1972.

U.S. Dept. of Agriculture. *Estimating Agricultural Costs of Production—Workshop Proceedings*. Washington, D.C.: ESCS-56, June 1979.

Vaughn, Karen. "Does It Matter That Costs Are Subjective?" *S. Econ. J.* 46(1980):702–15.

Wells, R. C., and S. R. Sutter. *1977 Dairy Farm Business Summary*. North Carolina State University. Agr. Ext. Ser., AG-39, rev. ed., Aug. 1978.

A Critique of Exchange Rate Treatment in Agricultural Trade Models: Comment

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In a recent article in this *Journal*, Chambers and Just criticize partial equilibrium models of trade which attempt to show the effect of currency devaluation on domestic prices. Three of their main points are (*a*) cross-price effects cannot be ignored, (*b*) the response of domestic prices to exchange rate disturbances may (but need not) be different from their response to foreign price disturbances, and (*c*) demand systems derived from weakly separable utility functions may be useful in constructing trade models. We read the Chambers-Just note with ambivalence because we have made all of these points ourselves, but surprisingly our 1977 paper was accused of advocating a contrary position. In addition to clarifying the misrepresentation of our work, we offer a comment on the authors' claim that there are neither theoretical nor empirical reasons for domestic prices to rise by no more than the rate of devaluation.

Concerning cross-price effects, any study of the effect of dollar devaluation on the demand for U.S. wheat cannot ignore the prices of other kinds of wheat and the prices of substitute grains. The distinguishing feature of our model which Chambers-Just describe as assuming zero cross-price elasticities (p. 251, 254), is that demanders distinguish wheat by country of origin. That cross-price effects are explicitly incorporated should be apparent from the following system of demand equations, but evidently it was not:[1]

$$Q_{ij} = f(P_{ij}^{D}, Z_i) \qquad i, j = 1, \ldots, n,$$

where the i subscript refers to the country importing wheat, and j refers to the country that is exporting wheat, and Z_i refers to exogenous demand shifters such as income and prices of substitute grain in the ith importing country. This system incorporates two kinds of cross-price effects: (*a*) $n - 1$ cross-price elasticities with respect to wheat supplied by countries other than j, and (*b*) cross-price elasticities with respect to other grains which enter through the Z_i's. For example, the demand for U.S. wheat in Japan depends on the price of U.S. wheat in Japan, the price of Canadian wheat in Japan, the price of Australian wheat in Japan, etc. Thus, the wheat prices are determined by a general equilibrium system, so that any disturbance that affects one of these substitutes also affects all the others.[2] In addition, we entered as an exogenous variable the price of corn. This class of models has some shortcomings, but failure to incorporate prices of related products is not one of them. Thus the contention of zero cross-price effects is gratuitous.

A possible shortcoming of our model is that wheat supply and prices of substitute grains are exogenous variables, but whether the benefits of a larger model are worth the costs in terms of additional complexity is a question without an easy answer. Even a model in which wheat supply and prices of other grains appear as endogenous variables is not fully general, because it ignores the feedback from grain prices to the exchange rate, substitution between grain and a broader class of goods, and substitution between goods, bonds, and money.[3] While there is some merit to the suggestion that trade models should incorporate a broader range of products, there is no logical end to this process until all domestic and foreign markets are included. Thus, Chambers-Just are vulnerable to the same Walrasian criticism that they make; i.e., some potentially important endogenous variables are omitted.

Domestic prices may not respond in the same way to exchange rate changes as they do to changes in foreign prices. Our wheat model takes this possibility into account by treating wheat as a differentiated product. U.S., Canadian, and Australian wheat are all substitutes, so that a disturbance such

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[1] After listing the own price elasticities for the various wheats, we stated that "From these basic elasticities, all the direct and cross-price elasticities can be derived." (Johnson, Grennes, Thursby, p. 629). On the same page we mentioned that "The major exogenous variables are demand shifters (income, price of substitute grain, imports by ROW). . . ." Another explicit statement is "Looking down that column, one can see the large changes are from a change in demand such as income or competing prices. . . ." (Johnson, Grennes, Thursby, p. 627).

[2] While our model does not assume zero cross-price elasticities, it is partial equilibrium in the sense that prices of substitute grains are exogenous variables. For example, a devaluation will affect prices of the n-types of wheat, and these cross-price effects are included in the model. However, the effect of devaluation on the supply and demand for corn is not endogenous and would enter through Z_i.

[3] In more general models there are both theoretical and empirical reasons to expect domestic prices to rise by no more than the rate of devaluation. On theoretical issues see Kemp chap. 14. On empirical work see the surveys done at the Federal Reserve by Lowrey-Hooper and Prakken. For an attempt to incorporate the money supply in analyzing agricultural markets see Shei and Thompson.

as a devaluation of the U.S. dollar will increase all their prices, but because they are imperfect substitutes, the prices will rise by different amounts. Also a 10% devaluation of the Canadian dollar will have a different effect on wheat prices than a 10% devaluation of the U.S. dollar. Thus we were surprised to read that our model requires that exchange rates and foreign prices have the same effect on domestic prices. The only restriction we have imposed on exchange rates is that only changes in the real exchange rate (the money exchange rate relative to the general price level) alter exports. Thus, the demand for U.S. wheat exports should be unaffected by a simultaneous increase of 10% in the dollar price of all foreign currencies and a 10% increase in all U.S. product prices, including wheat. As a theoretical matter our model permits a differential response to exchange rates and foreign prices, but the issue is ultimately an empirical one. Richardson has recently presented evidence which is contrary to the hypothesis of differential response. He regressed the Canadian price on the U.S. price and the exchange rate for twenty-two disaggregated products. He carefully held constant inflation, transport costs, and other shifters. In only three of twenty-two cases could he reject the hypothesis that the response to price was the same as the response to the exchange rate.

Chambers-Just propose to improve model specification by assuming a separable utility function in order to permit a two-state budgeting process by consumers. We can hardly disagree with this suggestion because it is a separable utility function permitting two-stage budgeting which underlies the demand side of our model.[4] Our exposition may not be perfectly lucid, but the following statement from our 1977 paper indicates that we have employed the notion of separability and found it to be useful in trade models. "His model, and our variant, can be derived by formally maximizing an underlying utility function in a two-stage process." (Grennes, Johnson, Thursby, p. 626). Paul Armington applied the idea to trade models a decade ago, and we have adapted a version of his model to grain trade. Collins and Wells also have employed demand systems based on separable utility to study trade in wheat and feed grains.

Chambers-Just deny that there are theoretical reasons to expect prices to rise by no more than the devaluation. At the same time they accept the so-called law of one price, which states that the domestic currency price (p) of a traded good will equal the domestic currency equivalent price ($e\gamma$) of the same product abroad, where e is the price of domestic currency in terms of foreign currency, and γ is the foreign currency price of the traded product. This can be expressed in terms of rates of change as

$$\frac{dp}{p} = \frac{d\gamma}{\gamma} - \frac{de}{e}.$$

By definition of a devaluation of the domestic currency $\frac{de}{e}$ is negative, and for a small country exporter $\left(\frac{d\gamma}{\gamma} = 0\right)$, domestic prices rise by the full amount of the devaluation, $\frac{dp}{p} = -\frac{de}{e}$. In the large country case, which is more appropriate for U.S. agricultural exports, the domestic price rises by less than the devaluation $\left(\frac{dp}{p} < \frac{de}{e}\right.$ in absolute value), provided that foreign currency prices fall $\left(\frac{d\gamma}{\gamma} < 0\right)$ as devaluation induces a larger volume of exports. This result is well known, and it is the basis of the common concern of policy makers that devaluation will worsen a country's terms of trade on the export side (see Robinson, chap. 1). As long as one invokes the law of one price, the domestic price will rise by more than the devaluation only if the foreign price rises. Somehow devaluation must improve the terms of trade on the export side. This is a curious condition because it is generally agreed that devaluation increases the volume of exports if not the value. If dollar devaluation causes Americans to export more bushels of wheat, how does this bring about an increase in the foreign wheat price? There may be good reasons for abandoning the law of one price (see Isard, Grennes, Johnson, Thursby 1978b) but Chambers-Just do not address that issue. Thus, there is a theoretical reason to expect domestic prices to rise by no more than the devaluation.

Whether domestic prices rise by more than devaluation is ultimately an empirical question, and work remains to be done. However, there is some relevant evidence that was overlooked by Chambers-Just. In a paper by Yandle which appeared in the same volume as one by Clark (which they cite), there is evidence on the effects of the dollar devaluation of 1971–74 on domestic wheat prices. The dollar fluctuated during the period and it depreciated by different amounts against different countries, but on the average his results are consistent with the proposition that a dollar devaluation by $X\%$ raised domestic wheat prices by no more than $X\%$.

A recent paper by Kreinin presented similar results on the responsiveness of domestic prices to currency changes. He estimated the effects of the 1970–72 currency realignments on prices of aggregate exports and imports of eight countries, including the United States. He also estimated the effect

[4] Whereas CJ suggest a weakly separable function, we assume a Pearce separable function which yields a more manageable parameter space than weak separability. See Johnson, Grennes, and Thursby (1979) for a discussion of the implications of this function.

of dollar devaluation on prices of certain disaggregated manufactured exports (SITC categories 5–8). His main result is that exporters "passed-through" nearly all of the effects of devaluation to foreign consumers in the form of lower prices. Foreign currency prices fell by 85%–100% of the devaluation, so that domestic prices rose by no more than 15%. Similar results were obtained for the disaggregated U.S. data.

We concluded that a devaluation of 10% raised wheat prices by 7%. Chambers-Just interpreted this as meaning that "devaluation had relatively little impact on the agricultural sector of the economy" (p. 249), and they contrasted our results with the 1974 paper of Schuh which they described as finding that "devaluations have been an important determinant of agricultural exports and have led, in part, to the high domestic prices of the early 1970s" (p. 249). A 7% increase in prices is not a negligible effect relative to many disturbances in the agricultural sector. Obviously whether devaluation is important or not depends on what it is compared with, and in the 1973–74 period dollar devaluation had a smaller effect on U.S. wheat prices than insulating trade policies of foreign governments which shifted demand on to U.S. wheat. On the issue of the importance of devaluation, we see no conflict between our results and Schuh's. His 1974 paper was important in that he directed attention to the relationship between exchange rates and agricultural prices, but he presented no empirical evidence on the subject.[5] In a subsequent discussion of some trade elasticities of Tweeten's, he offered the judgment that domestic agricultural prices would rise by 77% of the dollar devaluation.[6] This is so close to our figure of 70% that we deny the assertion by Chambers-Just that there is a conflict. The critique of the theoretical and empirical literature presented by Chambers-Just is incomplete and misleading. We cannot object to their empirical work on exchange rates and prices since they present none.

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References

Armington, Paul S. "A Theory of Demand for Products Distinguished by Place of Production." *Int. Monetary Fund Staff Pap.* 16(1969):159–78.

Chambers, Robert G., and Richard E. Just. "A Critique of Exchange Rate Treatment in Agricultural Trade Models." *Amer. J. Agr. Econ.* 61(1979):249–57.

Collins, Keith. "An Economic Analysis of Export Competition in the World Coarse Grain Market: A Short-Run Constant Elasticity of Substitution Approach." Ph.D. thesis, North Carolina State University, 1977.

Grennes, Thomas, Paul R. Johnson, and Marie Thursby. *The Economics of World Grain Trade*. New York: Praeger Publishers, 1978a.

———. "Some Evidence on the Nebulous Law of One Price." Paper presented to the annual meeting of the Southern Economic Association, Washington, D.C. 7–9 Nov. 1978b.

Isard, Peter. "How Far Can We Push the Law of One Price?" *Amer. Econ. Rev.* 67(1977):942–48.

Johnson, Paul R., Thomas Grennes, and Marie Thursby. "Devaluation, Foreign Trade Controls, and Domestic Wheat Prices." *Amer. J. Agr. Econ.* 59(1977):619–27.

———. "Trade Models with Differentiated Products." *Amer. J. Agr. Econ.* 61(1979):120–27.

Kemp, Murray C. *The Pure Theory of International Trade and Investment*. Englewood Cliffs, N.J.: Prentice-Hall, 1969.

Kreinin, Mordecai. "The Effect of Exchange Rate Changes on the Prices and Volume of Foreign Trade." *Int. Monetary Fund Staff Pap.* 24(1977):298–329.

Lowrey, Barbara, and Peter Hooper. "Impact of the Dollar Depreciation on the U.S. Price Level: An Analytical Survey of Empirical Estimates." Washington, D.C.: Board of Governors of the Federal Reserve System Res. Pap., 1978.

Prakken, Joel. "A Quarterly Model of Linkages between the Exchange Rate and Domestic Prices and Wages." Paper presented to the convention of the Midwest Economics Association, 6–7 Apr. 1979.

Richardson, J. David. "Some Empirical Evidence on the Law of One Price." *J. Int. Econ.* 8(1978):341–51.

Robinson, Joan. "The Foreign Exchanges." *Essays on the Theory of Employment*, chap. 1. Oxford: Blackwell, 1937. Reprinted in *Readings in the Theory of International Trade*, ed. H. S. Ellis and L. A. Metzler, pp. 83–103. Philadelphia, Pa.: Blakiston, 1949.

Schuh, G. Edward. "The Exchange Rate and U.S. Agriculture." *Amer. J. Agr. Econ.* 56(1974):1–13.

———. "The Exchange Rate and U.S. Agriculture: Reply." *Amer. J. Agr. Econ.* 57(1975):696–700.

Shei, Shun Yi, and Robert L. Thompson. "Inflation and U.S. Agriculture: A General Equilibrium Analysis of the Events of 1973." Paper presented to the AAEA annual meeting, Washington State University, Pullman, 30–31 July 1979.

Thursby, Marie, Paul R. Johnson, and Thomas Grennes. "A Disaggregated World Trade Flow Model." Paper presented to the annual meeting of the Southern Economic Association, New Orleans, 6–8 Nov. 1977.

Wells, Gary. "The Impact on Wheat Import Patterns from the Entrance of the United Kingdom into the

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[5] In his reply to a comment by Vellianitis-Fidas on his 1974 paper, Schuh stated, "To the charge that I offered little evidence (which appears to mean empirical evidence) in support of my central hypothesis, I plead guilty. My paper was an exercise in analysis and an appeal to the logic of the situation. An important goal, in fact, was to suggest hypotheses which might help us better understand our own economic history" (1975, p. 696).

[6] "If the 13% devaluation constitutes an equilibrium, the increase in the relative price of agricultural products after adjustments have worked themselves out may be something on the order of 10%. That is no small amount for a change in the internal terms of trade, however" (Schuh 1975, p. 699).

A Critique of Exchange Rate Treatment in Agricultural Trade Models: Comment

Michael R. Reed

In the May 1979 issue of the *Journal*, Chambers and Just (CJ) critically reviewed theoretical and empirical work on the role of exchange rates in agricultural prices and trade. CJ contend that the assumption of zero cross-price elasticities between commodities leads to an inaccurate portrayal of import demand and export supply functions and therefore an inaccurate portrayal of the effects of exchange rate changes on trade.[1] This author agrees with that contention. Incorporation of possible cross-price effects will clarify the effect of all variables in the system. However, this author feels that the remedy CJ have proposed for incorporating these cross-price effects in order to analyze the effect of exchange rate fluctuations is less than desirable. The proposition will be put forth that the inclusion of prices for commodities which are close substitutes (complements) to the good studied and an index of all domestic prices in the country studied is more sound in theory and practice than the cure proposed by CJ.

CJ argue that "a separate exchange rate variable (involving a weighted price index of other traded goods if feasible)" (p. 256), should be included in the equation for an excess demand function. This separate exchange rate variable would serve as a price index for all other traded goods. The structure under which this suggestion is derived is unclear. The exchange rate, in and of itself, is only relevant to excess demand as a deflator. It is a way of transforming prices into a currency which is relevant to producers and purchasers of goods in the country. Japanese producers and purchasers are interested in the yen price, not the dollar price. Therefore the idea of including the exchange rate as a separate regressor for an excess demand function is structurally unsound.

If the exchange rate is multiplied by a weighted price index of other traded goods, other problems develop. The first problem is that the "purchasing power parity theory" may not hold. Exchange rates may not reflect the purchasing power of the currencies involved. Therefore the exchange rate multiplied by a weighted price index of other traded goods does not accurately reflect the domestic currency price of goods in the country.

Second, there is the problem of price transmission for traded goods in a world where trade barriers are common. A change in the export price of a commodity may not be completely reflected in the internal price of the commodity in an importing country.

Finally, the exchange rate change also can have indirect effects on all goods in the economy. The exchange rate directly affects traded goods, but because of cross-price effects the price of nontraded goods also could change. These price movements for nontraded goods could then influence the excess demand function for the country. These cross-price effects between traded and nontraded goods are important, but certainly outside the scope of an empirical agricultural trade model.

A way of circumventing the problems of cross-price effects on nontraded goods and price transmission for traded goods is to include an index of domestic prices in the excess demand function. The structure of the relationships between exchange rates and domestic prices is not estimated, so the full effect of an exchange rate fluctuation would not be determined. However, the structure does allow all other domestic prices in the country to influence the excess demand for the commodity. Domestic price indices are available for most countries (International Monetary Fund).

Each commodity judged to have a relatively important cross-price elasticity can be included in the excess demand function. For example, the price of corn presumably would be included in the export supply function for wheat by the United States. Assuming no trade barriers or transportation costs, the internal price for a good (γ_j) is the world price for the good (P_j) multiplied by the exchange rate between the currency in which the world price is denominated and the currency of the country in question (e),

$$(1) \qquad \gamma_j = P_j e.$$

$P_j e$ would be included for own-price effects and for cross-price effects of commodities judged to be close substitutes (complements). In this way, first

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[1] Throughout the remainder of this paper the term excess demand will be used rather than import demand and/or export supply. If the world price is relatively high, the excess demand function will be an export supply function. If the world price is relatively low, the excess demand function will be an import demand function.

round effects of an exchange rate change for commodities that are close substitutes (complements) are embodied in the excess demand function. If the "purchasing power parity theorem" does not hold, the approach suggested by Bjarnson, McGarry, and Schmitz may be used. Instead of using yearly observations of the exchange rate, use a base period exchange rate for all observations.

Fletcher, Just, and Schmitz inserted the exchange rate as a separate regressor in their export demand model for North American wheat. CJ agree with this specification "in the case where all other individual price movements are unimportant" (p. 255). The rationale for this specification is that even when the world price and the exchange rate are the only factors influencing excess demand, there is no reason to restrict exchange rate changes to have the same impact as changes in the world price. This is only partially true. In the short run, an exchange rate change may be viewed as a more permanent development than a change in the world price. This may be true in a regime of fixed exchange rates, as was the case prior to 1971. An exchange rate change is less likely to be reversed than a change in the world price. Therefore, adjustment to an exchange rate change may be more rapid than an equal change in the world price. This situation is much less likely when exchange rates are floating, as they are now.

In the long run there is no intrinsic difference between exchange rate variations and world price variations of equal magnitude, even under a system of fixed exchange rates. There is no uncertainty as to the permanence of either price fluctuation. All adjustments in excess demand brought about by an exchange rate change may be completed after one year, while the adjustments may take longer for a change in the world price. However, after all adjustments have taken place, the impact of an exchange rate change is identical to a world price change of the same magnitude. In order to embody differential response lags for exchange rate and world price changes, a distributed lag framework is appropriate. The exchange rate and the world price of the commodity are included as separate regressors with a constraint that the sum of the weights for coefficients on the two regressors be equal. This allows a difference between short-run impacts of exchange rate and world price movements, but incorporates the postulate that the long-run impacts are identical. Wilson and Takacs used this technique to explain aggregate trade by several industrial countries. Their findings suggest that there are differential response lags for exchange rate and world price changes under a regime of fixed exchange rates.

With respect to agricultural trade models, lagged exchange rates and world prices may be linked to excess demand through the supply side. Supply of most agricultural commodities is influenced by lagged prices. Whether there is a differential response between exchange rate changes and world price changes because of uncertainty as to the permanence of the change for agricultural products is a matter for future empirical research.

Cross-price effects should be incorporated into theoretical and empirical models of agricultural trade, as CJ argued. But the structural excess demand relationship should not be distorted in order to capture the full effect of a change in the exchange rate. Exchange rate movements have far-reaching impacts on the entire economy of a country. Agricultural economists must either model the entire economy of the country or countries in question, or settle for estimates of partial effects of exchange rate changes.

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References

Bjarnson, H. F., M. J. McGarry, and A. Schmitz. "Converting Price Series of Internationally Traded Commodities to a Common Currency Prior to Estimating National Supply and Demand Equations." *Amer. J. Agr. Econ.* 51(1969):189–91.

Chambers, R. G., and R. E. Just. "A Critique of Exchange Rate Treatment in Agricultural Trade Models." *Amer. J. Agr. Econ.* 61(1979):249–57.

Fletcher, S. M., R. E. Just, and A. Schmitz. "The Impact of Exchange Rates and Other Factors on North American Wheat Export Demand." *World Food Crisis: Issues and Policy Alternative,* ed. Gordon C. Rausser. Amsterdam: North-Holland Publishing Co., forthcoming.

International Monetary Fund. *International Financial Statistics*. Washington, D.C., various issues.

Wilson, J. F., and W. E. Takacs. "Differential Response Lags to Price and Exchange Rate Change in the Foreign Trade of Selected Industrial Countries." Paper presented at the annual meeting of the Allied Social Science Association, Atlantic City, N.J., 16–18 Sept. 1976.

A Critique of Exchange Rate Treatment in Agricultural Trade Models: Reply

Robert G. Chambers and Richard E. Just

We would like to correct the seemingly substantive points made by Grennes, Johnson, and Thursby (GJT). One of the three main points they claim we make is misrepresented. We did not claim that their "model requires that exchange rates and foreign prices have the same effect on domestic prices." What we question is whether or not it is appropriate to force the exporter price of grains and exchange rate changes "to have the same relative effect on excess demand in the importing country" (Chambers and Just, p. 254).

Clearly from our discussion, we are questioning the applicability of "the assumption of zero cross-price elasticities between the traded agricultural commodity and all other goods for which prices are not constant or . . . other similarly restrictive assumptions," such as considering only corn cross-price elasticities (p. 251). In the Johnson, Grennes, and Thursby (JGT) model, for example, a certain percentage of change in, say, the Japanese price of U.S. currency and an equal percentage of change in the U.S. price of wheat (and corn if it is considered endogenously) has the same effect on Japanese demand for U.S. wheat (given JGT's assumptions). This is generally true only if wheat (and corn) is (are) the only commodity(ies) traded between the United States and Japan. But in 1976, for example, trade in all cereal grains amounted to only 15.5% of U.S. exports to Japan (United Nations). As clarified below, a change in the exchange rate can have more far-reaching effects than a change in U.S. grain prices because of implications for trade in all other goods and the related impacts on balance of trade and, in turn, the Japanese purchasing power for U.S. wheat.

The major part of GJT's other comments relate to the use of separability theory in demand specification and whether cross-price effects are adequately considered. On these points, we reply emphatically that they restrict many cross-price effects to be zero, and that their model (as they have described it in JGT does not include the essential generality afforded by separability. To explain these points, we will first review the concept of separability and Armington's application of it as a backdrop for our discussion. Consider a utility function $U = U(Q_{11}, Q_{12}, \ldots, Q_{1m}, Q_{21}, \ldots, Q_{n1}, \ldots, Q_{nm})$ where Q_{ij} is good j of commodity group i. Where Q_{ij} has price P_{ij} and m represents total income, the associated maximization problem is to maximize U subject to $\sum_{i=1}^{n} \sum_{j=1}^{m} P_{ij} Q_{ij} = m$. The theory of separability implies, under certain conditions (see Blackorby, Primont, Russell), that this consumer maximization problem can be broken into two stages such that income is first allocated to groups of commodities and then within the groups of commodities. The first-stage problem is to maximize $U^* = U(Q_1, Q_2, \ldots, Q_n)$ subject to $\sum_{i=1}^{n} P_i Q_i = m$ where P_i is a price index and Q_i is a quantity index for group i. The resulting group demand equations may be written as

$$(1) \qquad Q_i = Q_i(P_1, \ldots, P_n, m).$$

Given this allocation and expenditure, m_i,

$$(2) \qquad m_i = P_i \cdot Q_i(P_1, \ldots, P_n, m),$$

on group i, the within-group allocation problem is to maximize $U^i = U^i(Q_{i1}, \ldots, Q_{im})$ subject to $\sum_{j=1}^{m} P_{ij} Q_{ij} = m_i$. The resulting within-group demand equations may be written as

$$(3) \qquad Q_{ij} = Q_{ij}(P_{i1}, \ldots, P_{im}, m_i),$$

or, substituting (2) into (3), as

$$(4) \quad Q_{ij} = Q^*_{ij}(P_{i1}, \ldots, P_{im}, P_1, \ldots, P_{i-1}, P_{i+1}, \ldots, P_n, m).$$

In Armington's application of this framework, he specifies U^i as a constant-elasticity-of-substitution function,

$$U^i(Q_{i1}, \ldots, Q_{im}) = \left(\sum_{j=1}^{m} b_{ij} Q_{ij}^{-\rho_i} \right)^{-1/\rho_i},$$

from which one finds equation (3) to be of the form

$$(5) \qquad Q_{ij} = b_{ij}^{\sigma_i} m_i \cdot P_{ij}^{-\sigma_i} P_i^{\sigma_i - 1},$$

where $\sigma_i = 1/(1 + \rho_i)$. Or, finally, substituting (2) in (5) obtains the familiar forms used by Armington,

$$(6) \qquad Q_{ij} = b_{ij}^{\sigma_i} Q_i (P_{ij}/P_i)^{-\sigma_i}, \text{ or}$$

$$(7) \qquad \frac{Q_{ij}}{Q_i} = b_{ij}^{\sigma_i} \left(\frac{P_{ij}}{P_i} \right)^{-\sigma_i}$$

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which, of course, still basically correspond to equation (3).

Now return to JGT's claim that their model "can be derived by formally maximizing an underlying utility function in a two-stage process" (p. 626). Based on the description of the model in their earlier paper as well as in their comment, JGT postulate demand equations as

$$Q_{ij} = f(P_{ij}^D, Z_i),$$

"where Q_{ij} is quantity consumed in country i of wheat originating in country j, P_{ij}^D is consumer price in country i of wheat from country j, and Z_i is exogenous demand shifter for country i" (p. 621). In both their earlier paper and their comment, the exogenous demand shifters are identified as income and price of substitute grain. In addition, the earlier paper mentions imports by the rest of the world (which excludes their six endogenous countries). This specification is not a complete application of either Armington's model or separability. First of all, to follow the Armington specification, Q_{ij} must be specified following equation (6) as a function of an aggregate wheat quantity index for country i, the price in country i of wheat country j, and an aggregate wheat price index in country i; or following equation (5), as a function of country i total expenditures on wheat, m_i, along with the same two price variables; or following equation (7) with market shares, depending on relative prices. On the contrary, however, JGT do not specify Q_{ij} as a function of either total expenditure on wheat in country i or a total wheat quantity index in country i, and, although market shares are mentioned in their appendix (JGT), their equation (1) was not defined in terms of market shares or relative prices. Furthermore, the price of a substitute grain does not appear in Armington's equations (5), (6), or (7).

Because JGT have Q_{ij} as a function of income and a substitute grain price, their specification follows, instead, equation (4); but, in this context, the price indices of other groups are clearly omitted, and, hence, the associated cross-price elasticities are forced to zero. Corn is apparently the only other commodity besides wheat for which a cross-price is considered. Since the JGT demand function does not include all prices in the rest of the economy or variables such as m_i or Q_i which summarize the effects of prices in the rest of the economy, the JGT model (as it is described in JGT and GJT, this issue) ignores the possibility of substitution of wheat for all other commodities except corn as the prices of other commodity groups change. We did not claim that they consider no cross-price elasticities but rather that they do not consider the full impact of exchange rates that can enter through all cross-price elasticities (because many cross-price effects are not considered). Each of the other cross-price elasticities may be individually unimportant but the exchange rate can affect every cross-price (of traded goods) and the associated aggregate impact of all omitted cross-price elasticities may be significant.

Perhaps the confusion arises from GJT's peculiar notion of general equilibrium. They claim that, in their model, "the demand for U.S. wheat in Japan depends on the price of U.S. wheat in Japan, the price of Canadian wheat in Japan, the price of Australian wheat in Japan, etc. Thus, the wheat prices are determined by a general equilibrium system, so that any disturbance that affects one of these substitutes also affects all the others. In addition we entered as an exogenous variable the price of corn" (p. 249). We fail to understand how this system can be a general equilibrium system if the price of corn is exogenous. And what about all other commodities traded by, say, Japan? A change in the exchange rate affects all other traded commodities; hence, the balance of trade and associated purchasing power by Japan for wheat abroad can be affected much more extensively than if only wheat trade is considered.

Our critics acknowledge, in a footnote to their general equilibrium claim, that "the effect of devaluation on the supply and demand for corn is not endogenous and would enter through Z_i" (p. 249). But two further problems must be considered in this context. First, how can the effects of exchange rates on trade in other commodities and the related impacts on wheat trade enter their model when exchange rate effects are tied specifically to price effects, and wheat and corn prices are the only commodity prices included? Second, if corn prices are considered exogenously, then how can even the adjustment of corn price to exchange rate changes be considered in the kind of impact analysis reported by JGT (p. 622)? Corn prices would not simply adjust proportionally to exchange rates when the laws of supply and demand are at work; so without further information the effects would be unclear. Thus, based on the description of their model (JGT), it appears that the JGT model is not a general equilibrium model and is not capable of considering even the partial endogeneity of corn price without additional information.

To demonstrate these points clearly, consider the possibility of determining the total impact of an exchange rate change in equation (4). Differentiation obtains

$$(8) \quad \frac{dQ_{ij}}{de} = \sum_{j'=1}^{m} \frac{\partial Q_{ij}}{\partial P_{ij'}} \frac{\partial P_{ij'}}{\partial e} + \sum_{j'=1}^{n} \frac{\partial Q_{ij}}{\partial P_k} \frac{\partial P_k}{\partial e} + \frac{\partial m}{\partial e}.$$

According to the model in JGT, however, the effect of the exchange rate on imports is

$$(9) \quad \left(\frac{dQ_{ij}}{de}\right)_{JGT} = \frac{\partial Q_{ij}}{\partial P_{ij}} \frac{\partial P_{ij}}{\partial e} + \frac{\partial Q_{ij}}{\partial Z_i} \frac{\partial Z_i}{\partial e},$$

where the latter term of (9) includes only two of the

latter n terms in (8)—namely, $\partial m/\partial e$ and $(\partial Q_{ij}/\partial P_{k^*})(\partial P_{k^*}/\partial e)$, where k^* represents corn. Clearly, the true exchange rate effect in (8) can be much different than the JGT effect in (9).

We acknowledge the difficulty of including cross-price effects for all other commodities in estimating (judgmentally or otherwise) any demand equation. Empirical practices often lead to disregarding the less important cross-prices as do JGT. But, again, one must bear in mind that the exchange rate affects perhaps all cross-prices and, thus, while the impact of each individual (excluded) price may be insignificant, the aggregate impact of exchange rate included therein may be very significant. This point, rather than the three listed in GJT (this issue), is the main thrust of our earlier paper which, contrary to their assertion, they have not made previously. It is for this reason that the exchange rate must be given greater flexibility in a trade model than can be allowed by tying its effects to those of wheat and possibly corn prices or, indeed, to any small group of commodities.

Separability does not give one a license to ignore many factors but, rather, leads to a systematic way of including the effects of all factors through the convenience (and tractability) of several aggregate indices. Thus, contrary to the GJT claim that "there is no logical end to this process until all domestic and foreign markets are included," a logical and tractable end as far as including all variables (not necessarily as far as giving each full flexibility) is obtained by correct application of separability theory. For example, the Armington second-stage equation in (5) or (6) gives quantity demanded as a simple function of three variables—one which is commodity specific (P_{ij}), one which is group specific (P_i), and another which summarizes the effects of all other exogenous forces in the economy (m_i or Q_i). Clearly, by equation (1) or (2), m_i or Q_i is possibly affected by every other price in the economy. Thus, to determine the impact of a change in an exchange rate, say e, one cannot simply look at the effects of the exchange rate on the prices P_i and P_{ij} in equation (5) or (6) and their associated impacts on Q_{ij}; one must also consider the effects of the exchange rate on m_i in equation (5) or on Q_i in equations (6) and (7). That is, the total exchange rate impact in the Armington model is obtained only by considering the implications of equations (1) and (2) in equation (5) or (6); in point of fact, using either (5), (6), or (7) in this context clearly implies that

$$\frac{dQ_{ij}}{de} = \frac{Q_{ij}}{Q_i}\left[\sum_{i'=1}^{n} \frac{\partial Q_i}{\partial P_{i'}}\frac{\partial P_{i'}}{\partial e} + \frac{\partial Q_i}{\partial m}\frac{\partial m}{\partial e}\right] - \sigma_i\frac{Q_{ij}}{P_{ij}}\frac{\partial P_{ij}}{\partial e} + \sigma_i\frac{Q_{ij}}{P_i}\frac{\partial P_i}{\partial e}.$$

Hence, calculation of the exchange rate impact for a specific wheat demand requires knowledge of the elasticity (or derivative) of total wheat demand with respect to price indices of all groups of goods, the union of which exhausts the entire commodity set of the economy. Exchange rate impacts, thus, cannot be measured using only a second-stage equation of a separable scheme. Either equations representing both the first-stage allocation such as (1) or (2), as well as a second-stage allocation such as (3), (5), (6), or (7), must be used jointly to determine the full impact of an exchange rate change; or one can simply use equation (4), which is, in a sense, a reduced form of such a joint system. The observant reader will note that each of the possibilities suggested in our paper correspond to equation (4) and thus include, via the concept of separability, the effects of exchange rate on every price in the economy. The point of the meager two paragraphs which dealt with JGT in our earlier paper was that their model might be improved by giving the exchange rate this flexibility.

Turning to the comment by Reed, first note that in our original paper, we attempted to focus on the role of exchange rates in agricultural trade and the implications of trade theory for the modeling of exchange rates in empirical agricultural trade models. For purposes of brevity, we did not attempt to cover other aspects of demand modeling, such as the role of prices of close substitutes or trade barriers, which must be modelled with explicit reference to a given trade problem—sometimes as a departure from (but often not a rejection of) competitive theory. Nevertheless, Reed claims to disagree with our arguments, suggesting that "inclusion of prices of commodities which are close substitutes (complements) to the goods studied and an index of all domestic prices in the countries studied is more sound in theory and practice." Reed apparently insists on full treatment of the usual aspects of demand in addition to the exchange rate issues we raise. He also apparently has missed our note where "for simplicity of exposition, [we] assume that all goods are traded. Although somewhat unrealistic, this assumption does not change the qualitative results of the analysis. It does, however, considerably simplify the notation. The economy of notation hopefully contributes to the heuristic content of the argument" (p. 251). Since our assumption apparently has led to some confusion, however, we will present the general version of our model which includes nontraded goods.

To proceed, write the import demand and supply situation as follows:

$$\text{(10)}\qquad \begin{aligned} D_i &= f(\gamma, \mathbf{p}^*, M)\\ S_i &= g(\mathbf{p}, \bar{\mathbf{p}}, m)\\ Q_i &= S_i = D_i, \end{aligned}$$

where the notation follows our earlier presentation except that $\mathbf{p}^*$ and $\bar{\mathbf{p}}$ are taken to be vectors of prices for nontraded goods in the importing and exporting nation, respectively, and m is income in the exporting country. Now, totally differentiating the equilibrium condition under the assumption that $dM = dm = 0$ and rearranging, obtains

$$(11)\quad \frac{d\mathbf{p}_i}{de}\frac{e}{\mathbf{p}_i} = \frac{\zeta_i}{\eta_i}[(\eta^*_i)'(\mathbf{S} + \zeta^*_i) - (\epsilon^*_i)'\zeta^*_i - (\bar{\epsilon}^*_i)'\bar{\zeta}^*_i + (\eta^{**}_i)'\zeta^{**}_i] + \zeta_i = \tilde{\zeta}_i,$$

where again the notation follows our earlier presentation except that $\bar{\epsilon}^*_i$ is a column vector of cross-price elasticities of supply for the nontraded good prices, η^{**}_i is a column vector of cross-price elasticities of demand for nontraded good prices, and ζ^*_i and ζ^{**}_i are the respective vectors of exchange rate elasticities of the cross prices. Examination of (11) readily affirms that there remains no reason to restrict $\tilde{\zeta}_i$ to the unit interval. Hence, introduction of nontraded goods does not significantly change our qualitative results.

We do not understand what Reed means when he says "that the 'purchasing power parity theory' may not hold," and how this applies to our argument. According to Officer the general theory of purchasing power (*PPP*) implies that short run exchange rates are determined according to

$$es_t = f(PPP_t, \ldots),$$

where es_t is the short-run exchange rate and PPP_t is either the ratio or price levels in the two countries of concern or the ratio of the price indices for the two countries deflated by a base-period exchange rate. Clearly, *PPP* theory implies a causal link between these ratios and the short-run exchange rate. The validity of such a relationship indeed has been the subject of a large literature. However, how this relates to our suggestion to "weight the 'all other' commodity index by the exchange rate" (p. 255) is unclear since our suggestion is simply to deflate some appropriately defined price index for traded goods by the exchange rate, i.e., convert the price index into common currency terms with the other prices in the system. This will not lead to any inconsistency if the index is appropriately defined. What is called into question here is not the *PPP* theory but the validity of the law of one price. That this might not hold at all times because of, for example, barriers to trade, we readily recognize. It is for this reason that in our original paper we noted the Johnson, Grennes, and Thursby "model which takes account of trade restrictions would be a more appropriate setting for examining the importance of exchange rates than the more simple empirical models if sufficient flexibility of exchange rate elasticities *vis-à-vis* price elasticities were allowed." (p. 254).

Reed claims that "the exchange rate change can have indirect effects on all goods in the economy." He argues, however, as though we advocate excluding prices of nontraded goods in estimation of a foreign country's demand for imports. While our earlier theoretical model indeed excludes nontraded good prices for reasons given both above and in our original paper, our interpretation of the results of the simpler theoretical model does not. We, in fact, concluded that "one possibility is to construct separate price indices for 'all other' traded commodities and all nontraded commodities, weight the 'all other' commodity index by the exchange rate, and include both along with the own price (in the importing country) as separate regressors" (p. 255). Thus, we agree entirely with the argument that prices of nontraded goods should be included, if possible, in estimating foreign demand for imports.

We would further argue, however, that use of an index of all domestic prices may not properly deflate the prices of traded goods by the exchange rate and certainly does not consider the possibility of differential rates of adjustment to prices and exchange rates according to the Orcutt hypothesis. Hence, bias could be introduced in the estimation of the exchange rate elasticity of price and of quantity demanded. It should be noted further that some of the simpler models in our paper are proposed for the case where such price indices do not exist and where detailed treatment of demand by country is then infeasible because of data, budget, or time constraints. In these cases, the approach suggested by Reed is not enlightening.

We have argued in our "Critique" that if an index of prices of traded goods is not available, then a feasible but simplified approach may be to "treat the exchange rate as a price index for all other traded goods" (p. 255). Thus, for cases where a domestic price index is available and is representative of price levels of nontraded goods, our work and the model above suggest the same approach as proposed by Reed except that an additional generality is included by adding a separate exchange rate regressor. Thus, the general point made by Reed is, at least implicitly, subsumed in our original paper.

His additional point that prices of close substitutes should be included specifically is simply a further application of the theory of separability which can be made in our framework and with which we fully agree (and, incidentally, fully intended in our original work, although we did not want to take the space to explain already well understood practices in demand estimation). Ideally, one would like to be able to specify a utility function of the weakly separable form $U = F[U_1(D_1), U_2(D_2), U_3(D_3)]$ where D_1 represents the commodity of concern and its close substitutes and complements, D_2 is the bundle of all other nontraded goods and D_3 is the bundle of all other traded goods. The demand functions obtained from such a utility function can then be written as a function of the price indices for groups 2 and 3, the prices of the close complements and substitutes and income. Making similar arguments for the exporting country would then allow us to rewrite (10) as

$$(10')\quad \begin{aligned} D_i &= f(\gamma_i, \tilde{\gamma}, \Gamma, P^*, M) \\ S_i &= g(p_i, \bar{p}, P, \bar{P}, m), \end{aligned}$$

where $\tilde{\gamma}$ is the vector of prices of close substitutes and complements, Γ is the price index for traded

commodities, and P^* is the price index for nontraded commodities in the importing country; $\bar{p}$, P, and $\bar{P}$ are defined similarly. Specification in this manner would not involve bias in the estimation of exchange rate effects or of the role of other prices if the prices of other domestic goods are truly exogenous and the Orcutt hypothesis is not operative.[1] Any indirect effects of exchange rate changes on all goods in the economy would be included explicitly, although simultaneous-equation bias in the estimation of coefficients would occur just as in Reed's proposed model—unless the prices of other domestic goods are truly exogenous.

Finally, with respect to Reed's interpretation of our evaluation of the specification used by Fletcher, Just, and Schmitz (which is also attributed to Meilke and de Gorter in our earlier paper), he claims that we agree. If he will read closely, however, he will find that we do not agree and, in fact, conclude in the context of our theoretical model that "own price would appear denominated in the importer's currency. One can note that this is not the case with the empirical studies discussed below [which refers to Fletcher, Just, and Schmitz, and Meilke and de Gorter]" (p. 255). Thus, our earlier paper, in fact, agrees with Reed that when the very simple, two variable specification is used, a better approach is to include world (or foreign) price and exchange rate. In fact, these arguments were supported in the context of the Orcutt hypothesis (p. 255) which is exactly the phenomena of differential lag effects of prices and exchange rates to which Reed refers in criticizing Fletcher, Just, and Schmitz.

Reed argues that "the excess demand relationship should not be distorted in order to capture the full effect of a change in the exchange rate." We would argue, on the other hand, that respecification of demand equations to capture the "full effect" of a change in the exchange rate is not distorting the demand relationship but, on the contrary, avoiding distortion. We hope that our arguments are not taken as though we do not favor other improvements in demand specification that have been developed elsewhere. In addition to suggesting appropriate exchange rate treatment when sufficient data exists to use other sophisticated specifications with respect to other variables, we simply have attempted to suggest ways in which exchange rate flexibility can be considered where simplicity of specification is dictated by data scarcity, etc. We believe that agricultural economists should not "settle for estimates of partial effects of exchange rate changes," but should continually seek to improve specifications so that empirical results can be less partial in nature and take account of an ever-widening range of phenomena in the general economy which impacts upon the agricultural economy.

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[1] This statement, of course, ignores the existence of trade barriers. In those specific cases where trade barriers exist, they must also be given explicit consideration in econometric modeling. A logical and common approach in economics, however, is to first understand the behavior of a free market so that the effects of market imperfections can be considered in a meaningful way. Such an approach, for example, suggests that a change in the exchange rate may have a substantial effect on a country's import demand because of a demand shift due to prices of other traded goods even though its internal price is fixed by government regulation; this type of effect might be overlooked by simply focusing on trade barriers.

References

Armington, P. S. "A Theory of Demand for Products Distinguished by Place of Production." *Int. Monetary Fund Staff Papers* 16(1969):159–78.

Blackorby, C., D. Primont, and R. R. Russell. *Duality, Separability and Functional Structure: Theory and Economic Applications*. New York: American Elsevier, 1978.

Chambers, Robert G., and Richard E. Just. "A Critique of Exchange Rate Treatment in Agricultural Trade Models." *Amer. J. Agr. Econ.* 61(1979):249–57.

Fletcher, Stanley M., Richard E. Just, and Andrew Schmitz. "The Impact of Exchange Rates and Other Factors on North American Wheat Export Demand." *New Directions in Econometric Modelling and Forecasting for U.S. Agriculture*. ed. Gordon C. Rausser. Amsterdam: North-Holland Publishing Co., forthcoming.

Johnson, Paul R., Thomas Grennes, and Marie Thursby (JGT). "Devaluation, Foreign Controls, and Domestic Wheat Prices." *Amer. J. Agr. Econ.* 59(1977) 619–27.

Meilke, Karl D., and Harry de Gorter. "A Quarterly Econometric Model of the North American Feed Grain Industry." Paper presented to Economics Branch, Agriculture Canada, Ottawa, 27 Apr. 1977.

Officer, Lawrence H. "The Purchasing Power-Parity Theory of Exchange Rates: A Review Article." *International Monetary Fund Staff Papers* 23(1976):1–61.

United Nations. *Yearbook of International Trade Statistics 1977*, vol. 1. Dep. Int. Econ. and Soc. Aff., New York, 1978.

The Value of Unrealized Farm Land Capital Gains: Comment

Richard W. Dunford

In a recent issue of this *Journal*, Plaxico and Kletke (hereafter referred to as PK) analyzed several ways of valuing the unrealized capital gains on farm land. Relatively high rates of appreciation in land values, general price inflation, rising mortgage interest rates, and depressed returns in some agricultural sectors in recent years have enhanced the importance of evaluating land investment decisions. The PK analysis of the value of unrealized farmland capital gains is an important contribution to the work on this issue. However, there are a few conceptual problems with the PK study. Three specific topics are addressed in this comment: (*a*) the relationship between discount rates and inflation; (*b*) the conversion of capital gains into a tax-deferred income stream; and (*c*) the valuation of additional investment opportunities due to the appreciation of land values.

Discount Rates and Inflation

PK (p. 327) defined the present value of anticipated capital gains realized when farmland is sold as

$$(1) \qquad V_0 = \frac{(P_n - P_o)\,(1 - T_c)}{\{[1 + D\,(1 - T)]\,(1 + Z)\}^n},$$

where P_n is the value of the property when sold in the nth year, P_o is the purchase price of the property, T_c is the marginal tax rate applied to capital gains, D is the discount rate as determined by the opportunity cost of capital, T is the marginal income tax rate, and Z is the rate of general inflation in the economy. So, equation (1) stipulates that after-tax capital gains must be deflated by the increase in the general price level, and then discounted back into its present value.

As indicated by Adams (p. 539),

> The appropriate discount rate for individual (unincorporated) investors to use in computing present values is the rate of return available on other assets in the same risk class; this is the opportunity cost of alternative uses of invested funds. . . .

Using the opportunity cost approach, anticipated price inflation will be incorporated implicitly into nominal discount rates. A general inflation results in future returns from investments accruing in depreciated or deflated dollars. Realizing this fact, investors build an inflation expectation into their required rate of return. Therefore, the nominal discount rate for individual investors already includes an adjustment for anticipated inflation.

In equation (1), PK adjust their opportunity cost of capital for anticipated inflation by multiplying $[1 + D\,(1 - T)]$ by $(1 + Z)$, where Z is the general rate of inflation in the economy. Therefore, D must represent the real opportunity cost of alternative uses of invested funds, even though PK do not state whether D is in real or nominal terms.[1] Despite the *de facto* identification of D as a real discount rate, PK in their subsequent examples assume discount rates of 12% and 18% (p. 329). It is not realistic to claim that these are representative real rates of return from investments similar in risk to farmland. However, nominal discount rates of 12% and 18% are realistic when inflation expectations are relatively high. In summary, the opportunity cost of capital in the PK article is specified in real terms in their theoretical model, but nominal values are used in their empirical model.

Capital Gains as a Tax-Deferred Income Stream

As suggested by PK, the unrealized capital gains may be viewed as a "tax-deferred income stream with the tax being paid at capital gains rates when the property is sold or at the end of the planning horizon" (p. 327). Thus, equation (1) can be rewritten in an equivalent specification as

$$(1') \qquad V_o = \frac{\sum_{t=1}^{n} (P_t - P_{t-1})}{\{[1 + D\,(1 - T)]\,(1 + Z)\}^n} - \frac{(P_n - P_o)\,T_c}{\{[1 + D\,(1 - T)]\,(1 + Z)\}^n}.$$

This specification of the present value of unrealized capital gains simply distributes these gains

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David Walker, Gayle Willett, and an anonymous referee made several valuable suggestions which helped clarify and focus this paper.

[1] It would be double-counting to use a nominal discount rate and then multiply this discount rate by $(1 + Z)$ to adjust for anticipated inflation.

throughout the period of ownership. Because no capital gains are realized until the property is sold, property value increases in the ith year $(P_i - P_{i-1})$ must be discounted from the nth year to obtain their incremental present value.

Valuation of Additional Investment Opportunities

PK state that if some of the increase in equity in land each year is "available as a financial reserve or as an equity base for expansion" (p. 327), there is additional value on a flow basis from the annual equity increases. They claim to incorporate this phenomenon in their equation (2):

$$(2)\ V_1 = \sum_{i=1}^{n}\left[\frac{(P_i - P_{i-1})\,A}{\{[1 + D\,(1 - T)]\,(1 + Z)\}^i}\right] + \frac{(P_n - P_o)(1 - A) - (P_n - P_o)\,T_c}{\{[1 + D(1 - T)]\,(1 + Z)\}^n},$$

where A is the proportion of the increase in equity in land in a given year, due to price increases, that is available as a financial reserve or as an equity base for expansion (p. 327).

PK correctly declare that "equity increases can be viewed as increased reserves which improve financial ratios (reduce the degree of financial leverage) and/or increase financial flexibility" (p. 327–8). They then incorrectly assert that "annual land purchases, or other additional investments are in no way a necessary condition for increased equity to have value on a flow basis" (p. 328). This is incorrect because the benefits received by an investor from a reduced degree of leverage and/or increased financial flexibility have previously been captured in the model.

Since the appreciation in land values is fully anticipated, equity increases over the life of the investment (which improve financial security and flexibility) decrease the riskiness of this class of investments. This reduced risk lowers the opportunity cost of capital on farmland purchases. Thus, the benefits of the reduced risk associated with this class of investments are implicitly embodied in the appropriate discount rate a priori. The "availability" of equity increases produces no additional value unless the increased equity is used to make additional investments.

Because the capital gains on the farmland are not ually realized until year n, it is necessary to orrow to make additional investments. Equation (2) as given by PK does not incorporate borrowing against equity. If the farmland owner only uses his annual equity increases to finance additional one-year investments (as assumed by PK), the present value of the anticipated capital gains would be

$$(2')\ V_1 = \sum_{i=1}^{n}\left[\frac{(P_i - P_{i-1})\,(B)\,(D - r)\,(1 - T)}{\{[1 + D\,(1 - T)]\,(1 + Z)\}^i}\right] + \frac{(P_n - P_o)\,(1 - T_c)}{\{[1 + D\,(1 - T)](1 + Z)\}^n},$$

where r is the contract rate of interest, and $(P_i - P_{i-1})$ (B) is the total amount borrowed.[2]

If the farmland owner uses his accumulative equity increase to finance additional one-year investments, then the present value of anticipated capital gains would be

$$(3)\ V_2 = \sum_{i=1}^{n}\left[\frac{(P_i - P_o)\,(B)\,(D - r)\,(1 - T)}{\{[1 + D\,(1 - T)]\,(1 + Z)\}^i}\right] + \frac{(P_n - P_o)\,(1 - T_c)}{\{[1 + D\,(1 - T)](1 + Z)\}^n}.$$

This equation is identical to equation (3) in the PK article.

Comparison of Alternative Capital Gain Value Estimates

PK use equation (1), (2), and (3) in Models I, II, and III, respectively. Equations (1) and (3) are correct but (2′) should be used in Model II.

Table 1 contains a comparison of the value of capital gains using (2′) as opposed to (2). The following assumptions are identical to those used by PK: (*a*) 5% appreciation in land values; (*b*) 12% discount rate; (*c*) 15% marginal tax rate; (*d*) 0% rate of inflation; (*e*) ten-year planning horizon; (*f*) \$100,000 purchase price of the property; (*g*) 9% rate of interest on borrowed funds; (*h*) B is 1, giving an

[2] B is the ratio of the amount that can be borrowed to the amount of equity needed to support that borrowing. In other words, $\frac{1}{B+1}$ is the equity base required to finance further investment.

Table 1. Annual Values of Capital Gains Over a Ten-Year Planning Horizon: Equation (2) versus Equation (2′)

	Capital Gains			
	Equation (2)		Equation (2′)	
Year	Value	Present Value	Value	Present Value
	($)			
1	5,000	4,537	128	116
2	5,250	4,323	134	110
3	5,512	4,119	141	105
4	5,788	3,925	148	100
5	6,077	3,740	155	95
6	6,381	3,563	163	91
7	6,700	3,395	171	87
8	7,035	3,235	179	82
9	7,387	3,082	188	79
10	7,756	2,937	198	75
Flow value	62,888	36,855	1,604	940
End value	−4,717	−1,786	58,171	22,024
Total	58,171	35,069	59,775	22,964

Note: See table 1 in the PK article.

implied equity requirement of 50%; (*i*) 7.5% tax rate on capital gains; and (*j*) all of the equity increase is available as a reserve for additional investments in each year.

As shown in table 1, the present value of capital gains using equation (2) overstates the actual present value of $22,964, which is calculated by using equation (2′). This present value is based upon annual equity increases being used to finance additional one-year investments. As would be expected, this present value is less than the present value of capital gains when accumulative equity increases are used for additional investments (see Model III, PK, p. 328). The opposite result in the PK article clearly demonstrates the misspecification of their Model II. That is, by using equation (2) in Model II, PK came to the paradoxical conclusion that more value is derived from investing annual equity increases than from investing accumulative equity increases.

In a real world setting, the use of equity increases as a financial base for additional investments usually does not occur on an annual basis. When this type of investment does take place, the term of the investment usually exceeds one year. Thus, a more realistic scenario might involve the farmland owner using the accumulative equity increase at year 5 to finance another land investment with a five-year planning horizon. At year 10, both properties might then be sold. The present value of capital gains resulting from this scenario would fall somewhere between the estimates from equation (1) and equation (3).

In conclusion, under present economic conditions, land values can be expected to increase in nominal (and possibly, real) terms. Even though anticipated capital gains are not realized until the property is sold, equity increases due to appreciation in land values can be used to finance other investments. To the extent that this phenomenon occurs, the present value of anticipated capital gains will be increased. The exact amount of this increase depends upon a multitude of conditions, assumptions, and expectations.

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References

Adams, Roy D. "The Effects of Income Tax Progressivity on Valuations of Income Streams by Individuals." *Amer. J. Agr. Econ.* 59(1977):538–42.

Plaxico, James S., and Darrel D. Kletke. "The Value of Unrealized Farm Land Capital Gains." *Amer. J. Agr. Econ.* 61(1979):327–30.

The Value of Unrealized Farm Land Capital Gains: Reply

James S. Plaxico and Darrel D. Kletke

In the current economic setting, evaluation of capital gains is an important issue. In view of the paucity of work relating to the issue, professional dialogue can serve to focus attention on the problem and to contribute to the clarification of underlying issues. The recognition by authors cited in our original paper that capital gains are an important component of land values was a forward step. Our contribution was to suggest that unrealized capital gains have current value and to present two approaches (models) for evaluating unrealized gains. Dunford has raised several questions regarding our formulation and has suggested a modification of one of our models. We are pleased to have an opportunity to attempt to further clarify the issues involved.

Discount Rates and Inflation

Our discount rate (D) is in real, not nominal, terms and is the opportunity cost of capital to the individual (firm) for assets that are comparable in terms of risk and uncertainty. In our analyses we used discount rates (D-values) ranging from 0–24 in order to assess the impact of the different variables on calculated capital gains values using the different evaluation models. In the final draft we included only the 12% and 18% rates to conserve space. The rates used are assumed rates. We have no empirical or other basis for specifying the discount rate of farmland purchasers nor does Dunford provide a basis for asserting that the rates we assumed are nominal rates. We suspect that the appropriate D-value varies among individuals depending on alternatives and capital available, expectations, and individual evaluations of risk and uncertainty.

Some of the confusion in the literature regarding discount rates arises because authors and practitioners tend to combine most or all asset-pricing variables into a single capitalization (not discount) rate. It would be as logical to reflect an expected rising stream of net revenues and/or rising asset prices by adjusting the discount rate downward as to reflect expected inflation by adjusting the discount rate upward. In practice, land appraisers do sometimes combine all factors considered to be relevant into a single capitalization rate. Such a capitalization rate clearly cannot properly be viewed as the discount rate in either real or nominal terms.

It should be noted that the purpose of our paper was to examine the structure of the value of unrealized capital gains. For such an analysis, it is clearly important to identify, within the context of the alternative evaluation models, the impact on capital gains values of the individual variables thought to be important. To combine the discount rate and the expected inflation rate would obscure their separate effects.

Capital Gains as a Tax-Deferred Income Stream (Wealth Value)

Our model II equation (2) is essentially a wealth approach to evaluating unrealized capital gains. The basic argument is simply that an increase in wealth due to an unrealized capital gain has a current value which, when adjusted for an anticipated capital gains tax, could be as high as an equal after-tax income for the same period. In terms of our model II, an $A = 1.0$ implies that a dollar of after-tax capital gains is equal in value to an after-tax dollar of ordinary income. Where current cash flow is a problem, the unrealized gain would have a lesser value than an after-tax dollar of ordinary income, hence an $A < 1.0$. Also, if the unrealized capital gain is not viewed as being secure, that is a subsequent capital loss is viewed as possible, this expectation would be reflected by an $A < 1.0$.

In retrospect our original explanation of Model II invites misinterpretation. We emphasized too much the utilization of unrealized gains as an equity base for expansion. However, Dunford's model embodied in his equation (2′) is a convolution of our Model III and has no relationship to our Model II for which he apparently suggests his (2′) as a substitute. Unfortunately, Dunford has failed to recognize that our Model II is an approach to the evaluation of capital gains in terms of increased (but unrealized) wealth while our Model III evaluates capital gains in terms of the earning capacity of increased borrowed capital based on the equity provided by capital gains in land. This oversight led Dunford to several erroneous conclusions.

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Our Model II embodies a concept similar to the wealth approach of Bhatia, and our Model III is similar to Bhatia's income approach. In short, we reject the usual approach to capital gains (our Model I) because this model assumes a zero current value for unrealized gains. Our Models II and III represent two approaches to the evaluation of unrealized gains. The existence of a current value of unrealized capital gains has been established theoretically (Baquet) and empirically (Bhatia). Baquet (p. 76) treats capital gains as equivalent to income. Bhatia, in estimating consumption functions, derived coefficients that were positive and significant for both realized and unrealized gains although the coefficients associated with unrealized gains were smaller than those associated with income.

As suggested elsewhere "economists frequently ignore the current value of unrealized capital gains because they think of returns as annual income flows and view managers as maximizing a utility function closely related to annual income flows. . . . Wealth accumulation may be superior to income as a simple proxy of the utility surface" (Plaxico p. 1099). The last statement may well characterize a significant number of individuals currently active in the land market.

Capital Gains as the Basis for Additional Income (Income Approach)

It is difficult to imagine a situation that would result in borrowing against an appreciation-generated equity only in the year it occurs. Thus the relevance of Dunford's equation (2′) is not obvious. Assuming a zero inflation rate, Dunford's equation (2′) is identical to our Model II. Thus Dunford's table 1 does not appear to offer additional insight. Further, his conclusions based on our table 1 are incorrect. For example he states, "by using equation (2) in Model II, Plaxico and Kletke come to the paradoxical conclusion that more value is derived from investing annual equity increases than from investing accumulative equity increases" (p. 262). Actually, in our table 1 we compare results from our wealth (Model II) and earnings (Model III) models. Our conclusion is that Model II (the wealth model) generates a higher capital-gains value estimate than our Model III (the earnings model), assuming $A = 1.0 = B$. However, we point out that a comparable degree of leveraging for the two models, i.e., $A = 1.0$ and $B = 3.0$, produces similar estimates from the two models (p. 329).

In our paper we explicitly recognized that in many cases not all unrealized equity would be utilized as an equity base for expansion or for other investments because such equity use often will not occur on an annual basis (p. 327). This was accounted for by the "A" value in our Model II and the "B" value in our Model III. Although not perfect, we consider this approach to be superior to suggesting, as Dunford has, that a "real world" value would fall somewhere between values derived by assuming full investment for one year of annual equity increases and full investment of accumulated equity increases. Elsewhere we have shown the effect of various levels of "A" and "B" values (Kletke and Plaxico).

Conclusions

We can accept readily the conclusion that "the exact amount of this increase depends upon a multitude of conditions, assumptions, and expectations" (Dunford p. 262). However, Dunford has not presented data or rationale that refute the basic logic of our paper. Thus we continue to consider both our Models II and III to be among the reasonable and valid hypotheses of the structure underlying the value of unrealized gains. Hopefully, our paper and the Dunford comments contribute to a better understanding of the issues involved. However, much research of both a conceptual and empirical nature remains to be done.

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References

Baquet, Alan E. "A Theory of Investment and Disinvestment Including Optimal Lines, Maintenance and Usage Rates for Durables." Ph.D. thesis, Michigan State University, 1978.

Bhatia, Kul B. "Capital Gains and the Aggregate Consumption Function." *Amer. Econ. Rev.* 62 (1972):866–879.

Kletke, Darrel D., and James S. Plaxico. *Farmland Investment Value Appraisals and Purchase Feasibility Analysis.* Oklahoma State University Agr. Exp. Sta. Res. Rep. No. P-776, Oct. 1978.

Plaxico, James S. "Implications of Divergence in Sources of Return in Agriculture." *Amer. J. Agr. Econ.* 61(1979):1098–1102.

Plaxico, James S., and Darrel D. Kletke. "The Value of Unrealized Farm Land Capital Gains." *Amer. J. Agr. Econ.* 61(1979):327–30.

The Influence of Consumer Price Information on Retail Pricing and Consumer Behavior: Comment

W. H. Lesser and W. K. Bryant

In a recent article Devine and Marion concluded that improved retail food price information during a five-week experimental period in Ottawa-Hull in 1974 caused (in relation to the control market) a reduction in price dispersion among the reported stores, a decline in the average level of prices, and an increase in consumer satisfaction (pp. 230–35). These conclusions, if substantiated, have considerable significance for public policy, especially during periods like the current one of rapidly rising food prices. We believe that the results reported in this study warrant a reappraisal because (*a*) the control in this study (Winnipeg) does not fulfill the statistical conditions normally required for a control, and (*b*) causality between price information and price movements is established through what we consider to be inadequate statistical procedures. We believe also that there are valid alternative explanations for the pricing behavior observed during the experiment and that causality cannot be inferred from the results presented by Devine and Marion (DM).

The authors principally based their conclusions concerning the causal relationship between price information and average price levels on the following observed factors; prices declined more in the test area than in the "control" area (pp. 232–3), and price declines were greater during the six weeks after the beginning of the public price reporting project than occurred during the pre-information period, followed by an increase of 8.8% by the end of the research period (pp. 230, 232).

The use of Winnipeg as a control is questionable because of notable differences in basic characteristics such as the four organization concentration ratio [84.2 in Winnipeg and 71.0 in Ottawa in 1973 (Mallen, table 3–5B)]. Additionally as Blake et al. state in relation to a project designed to replicate the DM study, "spurious effects could readily lead to mistaken conclusions if a single test market were compared with a single control market" (p. 27).

A likely explanation for the observed decline in the DM index during the publication period is the coincidence of the reporting period with seasonal price declines in Ottawa-Hull. Seasonal declines are a common occurrence in Ottawa in October (Food Prices Review Board, p. 18). No mention is made of price seasonality in Winnipeg. In fact the authors' own figure, which uses Statistics Canada data, indicated a price index decline beginning in August, a month prior to the experimental price reporting (fig. 2, p. 233). Thus, the study may have measured a seasonal price decline and attributed it to the competitive effect of price reporting.

DM also exaggerate the overall effect of price reporting by including the decline noted for the week of 2 November with the effective price reporting period (table 1, p. 231). The effective reporting period refers to the date of the report advanced by two weeks, the period considered necessary for the store response to be observable (footnote 1, p. 230). However, 2 November followed 12 October by more than two weeks and followed by more than a week the apparent announcement of the termination of price reporting during the week of 19 October (Food Prices Review Board, p. 9). Thus, this last observation would seem to fall outside the period affected by the experimental price reporting. Excluding it, the total price decline associated with the experiment was 4.8%. From this must be deducted the "2 or 3 percent discrepancy due to sampling error . . ." announced as part of the price reporting program (Food Prices Review Board, p. 35). Thus, the maximum decline attributable to the experiment would have been less than 2%, not the 7.1% claimed by DM (p. 230).

The apparent anomaly between the indexes composed by DM (table 1, p. 231) and that reported by Statistics Canada (figure 2, p. 233) is troubling. For October and early November the DM index is generally flat, while the Statistics Canada (SC) index rises more than one point. Because the market baskets are composed of similar, commonly consumed items (the SC basket included 84 items rather than the 65 items sampled by DM), a possible interpretation is the shifting of margins from those items included in the DM market basket to other products, including those sampled by SC. Such selective shifts in margins seem plausible "because of the possibility that some retailers were able to discern the composition of the (Devine and Marion) basket by the end of the publication phase" (Food Prices Review Board, p. 17). Store management may have been able to discern the basket composition from

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those items most commonly consumed by the average Canadian family. Or, as has been suggested by former Food Prices Review Board employees familiar with the study, the price reporter may have acquiesced and revealed the entire item list to store management.

The relationship between interstore market basket price dispersions and price reporting was deduced by comparing dispersions during the effective experimental period with the before and after period. Taking a closer look at the data, the effect of the experiment on price reporting also seems to have been exaggerated. The lowest recorded dispersion (5.4%) did occur during the reporting period, but the average percent spread of 7.7% during the effective reporting period (28 September–26 October) was higher than for two five-week periods in the prepublication phase (7.8%, 7 June–5 July and 7.5%, 26 July–23 August). Because spreads were quite volatile during the reporting period the comparison of average spreads over periods of the same length would seem to be preferable to the authors contrasting averages from the twelve-week period prior to the five-week publication period (p. 232). Thus, price reporting did not have a clearly positive effect on reducing price spreads among stores.

Our concerns reduce to a disappointment that DM did not do a more complete statistical analysis of their data. Their's is a gross analysis of the data, when what is needed is an estimate of the net effect of price reporting holding other factors constant. A more thorough analysis would include a means of adjusting the data for seasonality either by using index deflators or proper employment of controls and allowing for shifts in store ranks and margins which occur independently of the reporting experiment.[1] The application of these procedures will provide less ambiguous insights into the short-term relationship between food prices and improved information.

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[1] One model specification that incorporates the suggested modifications is as follows:

$$P_{tj} = a_0 + a_1 T_{1t} + a_2 T_{2t} + a_3 T_{3t} + \sum_{i=1}^{J-1} a_{4i}\, SD_{tj}^{i}$$
$$+ \sum_{i=1}^{J-1} a_{5i}\, SD_{tj}^{i} T_{1j} + a_6\, SR_{t-1,j} + a_7\, RP_{tj} + a_8 SR_{t-1,j}\, RP_{tj}$$
$$+ \sum_{i=1}^{J-1} a_{9i}\, SD_{tj}^{i} SR_{t-1,j} RP_{tj} + e_{tj},$$

where

P_{tj} is weighted price index in week t in store j;
T_{1t} is t, a linear trend variable;
T_{2t}, max $(T_{1t} - 11, 0)$;
T_{3t}, max $(T_{1t} - 24, 0)$;
SR_{tj}, rank of store for store j in week t, a rank of one indicates the lowest price store;
SD_{tj}^{i}, 1, if observation is from store i ($i = 1, \ldots, j-1$), 0, else;
$RPtj$, 1, if observation is from reporting period, 15 September through 12 October, 0, else;
e_{tj}, random disturbance term.

The first three variables control for trend and seasonality. Systematic differences in price levels among stores are captured by the store dummies, SD_{tj}^{i}, while the interaction between store dummies and the line trend, $SD_{tj}^{i}T_{1t}$, measures systematic alterations in marketing strategies. Overall adjustment to price reporting will be caught by the period dummy, RP_{tj} while the interaction between store rank and the period dummy, $SR_{t-1,j}\, RP_{tj}$, captures the specific effect of publishing ranks. The last term, $SD_{tj}^{i}\, SR_{t-1,j}\, RP_{tj}$, is designed to pick up store specific differences in response to the reporting experiment.

References

Blake, R., R. Boynton, V. McCracken, and J. Uhl. "Retail and Food Price Reporting Implications for Consumers, Market Behavior and Price Levels." Paper presented at the Market Information and Price Reporting Conference, University of Wisconsin, Madison, 24 May 1979.

Devine, D. G., and B. W. Marion. "The Influence of Consumer Price Information on Retail Pricing and Consumer Behavior." *Amer. J. Agr. Econ.* 61 (1979):228–37.

Food Prices Review Board. *Food Price Comparisons.* Ottawa, Apr. 1975.

Mallen, Bruce. *A Preliminary Paper on the Levels, Causes and Effects of Economic Concentration in the Canadian Retail Food Trade: A Study of Supermarket Market Power.* Ottawa, Canada: Food Prices Review Board Ref. Pap. No. 6, Feb. 1976.

The Influence of Consumer Price Information on Retail Pricing and Consumer Behavior: Reply

D. G. Devine and B. W. Marion

Although in the main we disagree with the comments of Lesser and Bryant (LB), we welcome the opportunity to discuss further some of the points they have raised. The influence of increased information on the performance of oligopolistic markets is relatively unexplored, either theoretically or empirically. Dialogue and debate should be encouraged.

LB make several criticisms of the methodology and interpretations of our study. We will discuss them in the order that they are raised.

The use of Winnipeg as a single control market is questioned. We acknowledge the experimental design limitations of a single test-single control experiment. In order to test for internal and external validity, a four-market design was originally planned (two test and two control). Unfortunately, the Food Price Review Board would agree to only a two-market design; we are, therefore, unable to determine if the pretest consumer survey in the test market influenced the response of consumers to the price comparison program and/or affected their answers to the post-test consumer survey. Given the nature of the consumer questionnaire and the relatively small percentage of consumers who answered it, it is doubtful that it significantly affected the market response of consumers to the price comparison information; however, we have no way of testing this assertion.

Given this limitation of the research design, we do not agree that Winnipeg was an inappropriate control market. Winnipeg and Ottawa (the test market) are comparable in population, similar in their French and English cultural backgrounds and sufficiently separated spatially so that the control market was not influenced by the test market treatment. The four-firm concentration ratios, while not identical, were very high in both markets (84 and 71, respectively). The difference in four-firm concentration would be of greater expected importance if the level of prices in the two markets were being compared rather than the change in price. Although there are theoretical grounds for expecting price adjustments to be different in concentrated oligopolies than in competitive markets, there is no theoretical or empirical basis for expecting that short-run price changes within two highly concentrated oligopolies will be significantly affected by differences in market concentration.

One possible limitation of the two markets selected is the difference in the sources of supply and, hence, the possibility of different seasonal price patterns. This brings us to the second criticism of LB—that causality between the price information program and price declines in Ottawa-Hull was not adequately demonstrated because price seasonalities were not considered. This is a valid concern in any temporal pricing study. Food prices in Canada have shown a seasonal decline in September during the 1970s. Statistics Canada's monthly food price indices for Ottawa, Winnipeg, Toronto, and all Canada for the seven years 1971–73 and 1975–78 are shown in figure 1. Although there are slight differences in the seasonal patterns in the three metropolitan areas, they are generally similar. Compared to the August price indices, September prices average 1.26% lower in Ottawa, .40% lower in Winnipeg, 1.23% lower in Toronto, and .90% lower for all Canada. September and October indices are essentially identical in all three of the metropolitan areas. Based upon these data, any substantial differences in price movements in Ottawa relative to Winnipeg are unlikely to be due to differences in seasonal price patterns.

Although prices in Ottawa and all Canada typically have a seasonal dip in September, this is not true in all years. In 1974, Statistics Canada's price indices for food consumed at home in all Canada rose monotonically from 137.7 in April to 153.3 in December (1971 = 100). Price indices for Winnipeg and Toronto also showed a consistent upward movement throughout this period. In Ottawa, however, Statistics Canada data indicate a drop in price in September followed by a further drop in October (figure 2). There is no evidence that these declines are due to seasonal price movements.

There are other reasons why it is difficult to consider seriously LB's seasonality contention. First, it flys in the face of simple logic. A credible and simple comparison of prices for one-half of the supermarkets in a city would have no effect on prices only if consumers and retailers did not respond to such information. The only situations in which this seems conceivable are either where the

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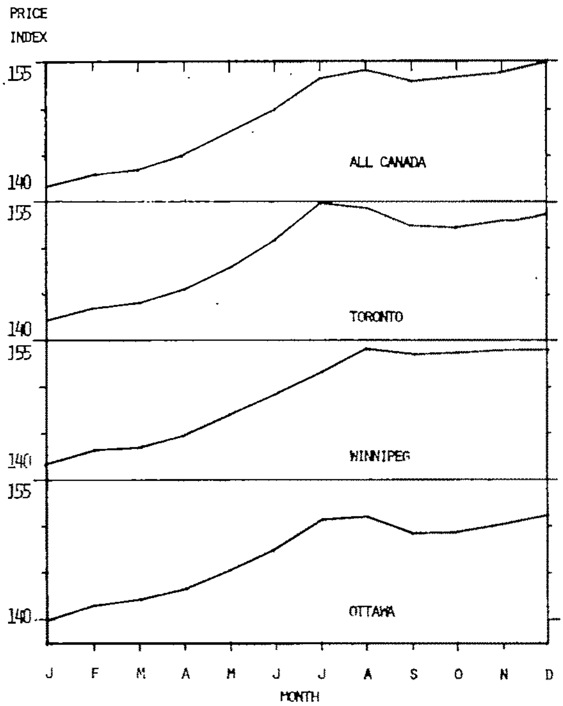
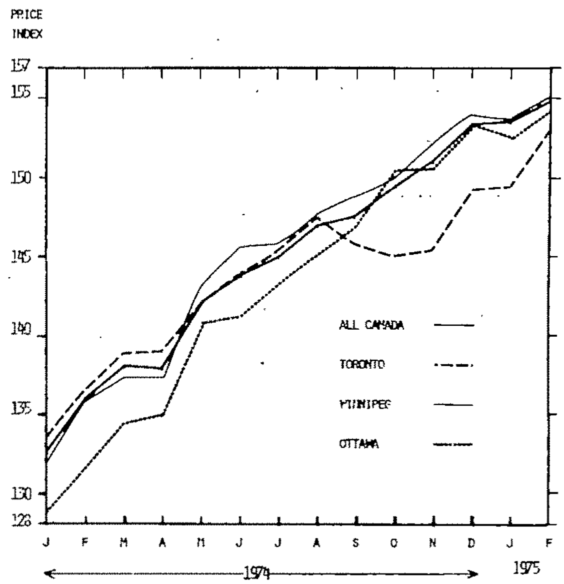
These comments do not necessarily reflect the views of the U.S. Department of Agriculture.



Source: Statistics Canada, CANSIM Data Retrieval.

Figure 1. Average monthly price index for food at home—1971–3 and 1975–8 (1971 = 100)



Source: Statistics Canada, CANSIM Data Retrieval.

Figure 2. Consumer price index of food at home January 1974 to February 1975 (1971 = 100)

distribution of prices perfectly reflects the perceived value of the product-service offers of different retailers, or where perfect collusion exists. Both are unlikely in our opinion.

In addition, our first-hand experiences in conducting the study are helpful in assessing causality. During the information-publishing period, retailers phoned the Food Price Review Board daily to check on their standing or to complain about losing sales. Consumers called to obtain information on store ranks and price changes. Retailers and their lawyers addressed the Board en masse to complain about the cutthroat competition being imposed upon them. Some threatened lawsuits. It was obvious to anyone in the market that something dramatic had happened. It was certainly not a seasonal event.

Because of the way figure 2 in our article was drawn, LB mistakenly conclude that the price decline in Ottawa began in August. Statistics Canada collects data only once a month during the first week of each month. Thus, the price decline occurred in early September. Even with this correction, however, LB are correct in noting that Statistics Canada indicates a price decline in Ottawa before the start of the price information program. In addition, Statistics Canada data indicate a somewhat different price pattern during September-November than the price data collected as part of our study. Although we have reexamined the sampling and weighting procedures used in developing the two data sets, we are unable to account for this difference. There are several differences in the methodologies: the sampling and weighting of stores, and the number, brands, and weighting of products price checked. Thus, the two data sets are expected to exhibit some differences. However, they are also sufficiently similar that the same basic price patterns should be evident. Without data on the stores, products, and brands actually price-checked by Statistics Canada, we are unable to reconcile the differences. We are confident of the accuracy of the price data developed by our price check teams. Enumerators were carefully trained, observations were randomly double checked for accuracy, and the items and brands to be checked were carefully specified. A 2% to 3% error for individual store indices was the maximum encountered.

LB misinterpret this error percentage as applying to the average price index for Ottawa-Hull. Because this was the maximum error for individual store indices, the average calculated for twenty-six stores would be expected to contain offsetting errors. The maximum error expected for the price index for the total market would be much smaller than 2%–3%.

LB indicate the overall effect of price reporting was exaggerated by including the week of 2 November in the calculation and ignoring the error margin discussed above. Although no price comparisons were published during the week of 26 October, retailers and consumers were not informed of the cessation of the program until the latter part of the week of 2 November—the time when price checks were being made for that week. Price

changes made early in that week (retailers generally make weekly price changes on Monday–Wednesday) may well have assumed the price comparison program was still in operation. In addition, neither theory nor empirical evidence defines the promptness nor duration of competitive responses to disequilibrating stimuli. Given the shift in patronage that occurred as a result of the price information program and the continuation of price monitoring through October and November, the competitive behavior of retailers may have been influenced by the information program for several weeks after publishing was ceased. Thus, our estimates of the overall effects of the program—while hardly precise—do not appear to be exaggerated.

LB also contend that the estimated effects on price dispersions in Ottawa-Hull were exaggerated because a twelve-week rather than a five-week period was used for comparison; in addition, the selected period was immediately prior to the information program. There is no uncontestable procedure for selecting a base period to compare with the test period. The average price dispersion of 7.8% during the information program could have been compared with the average dispersion during the five-week period prior to the program (11.4%), the twelve-week period prior to the program (9.7%), the entire nineteen-week pretest period (9.4%), or several other arbitrarily selected periods.[1] Our estimate of the information program effects may be incorrect; however, one can argue as easily that it is understated as that it is exaggerated.

Finally, LB express their disappointment that we did not do a more complete statistical analysis of the data and suggest a model that would provide estimates of the "net" effect of an information program. The appropriate statistical analysis for such an experimental venture is not easy to define. We welcome the ideas and suggestions of others. In this case, we do not feel that LB have demonstrated that our analysis was deficient or that their model holds promise for more penetrating and accurate interpretations. Their main criticism of merit is the inconsistency noted between the two price data sets. This is a data problem, not a statistical analysis problem.

A model similar to the covariance model suggested by LB was applied to a price information study in Saskatchewan during 1975–76. Such models are designed on the premise that each cross-sectional unit and each time period are characterized by their own special intercept (and/or slope). As Kmenta states, "If the model is correctly specified and the classical assumptions are satisfied, the OLS estimates . . . will be unbiased and efficient" (p. 517). The problem is accurately specifying the model for an oligopolistic market environment. Experience in applying the model to the Saskatchewan study revealed serious specification and multicollinearity problems, particularly for the slope and intercept dummy variables. When both dummy variables were included in the model, coefficient estimates were highly unstable.

Where a price comparison information program is a one-time intrusion into a market operation, we believe pricing behavior in carefully selected control markets is more likely to reveal the effects of nonexperimental factors than the inclusion of seasonal dummy variables. Seasonal price patterns vary considerably from year to year. In the Ottawa case, use of the LB model with a seasonal dummy might have indicated erroneously that the price decline was due to seasonal factors when in fact no seasonal declines were evident in other Canadian cities. We also question the inclusion of an independent variable on store rank which is linked to the dependent price index itself. Accurately specifying the appropriate time lag in a store rank variable could prove difficult because the lag in firm response may change over time and may vary from firm to firm.

With greater experience, models of the general type suggested by LB may be modified so as to provide more rigorous analysis of price information experiments. To date, however, simpler statistical analyses have provided the most useful and consistent insights.

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[1] An unexpected benefit of reexamining table 1 in our article is the discovery of several errors. The correct percentage differences are as follows:

	Ottawa-Hull by Firm	Ottawa-Hull by Store
19 May		13.40
7 June	5.80	8.76
21 June	3.62	5.99
2 August	3.67	
9 August	4.16	6.49
14 September	6.82	
30 November	6.14	

References

Devine, D. Grant, and Bruce W. Marion. "The Influence of Consumer Price Information on Retail Pricing and Consumer Behavior." *Amer. J. Agr. Econ.* 61(1979):228–37.

Kmenta, Jan. *Elements of Econometrics.* New York: Macmillan Co., 1971.

Milk Prices and the Public Interest
(William D. Dobson, University of Wisconsin-Madison, Chairperson)

Welfare Impacts of Milk Orders and the Antitrust Immunities for Cooperatives

Robert T. Masson and Philip M. Eisenstat

Many agricultural programs are being seriously reconsidered, including the Capper-Volstead partial antitrust exemption for cooperatives and the Federal Marketing Orders. We focus on the dairy industry, concentrating on the interface between monopoly, the Capper-Volstead Act, and the Orders. Using social cost-benefit analysis, we estimate that in the 1970s cooperative milk monopolies cost society more than $70 million a year, and that the Orders are partially responsible for these monopolies. These monopolies could have been avoided, and, once eliminated, could be avoided in the future with small changes in the Capper-Volstead exemption.

Capper-Volstead and Federal Milk Orders: Their Goals in Perspective

The Capper-Volstead Act of 1922 had two basic goals. The first goal was "that individual farmers shall be given . . . the same unified competitive advantage—and responsibilities—available to businessmen acting through corporations as entities" (*Maryland and Virginia Milk Producers* 362 U.S. 466). Without the Act, farmers who acted jointly in marketing would have run afoul of the Sherman Act unless they merged their farm assets. The second goal was "equalizing the bargaining power of the individual farmer in the relatively more concentrated markets in which he buys and sells" (National Committee, p. 208).

Under the antitrust laws neither corporations nor cooperatives are prohibited from possessing monopoly power, but neither may "monopolize." Monopolization is generally defined as predatory, coercive, and exclusionary acts and practices used to gain or maintain market power.

Corporations may not undertake mergers or joint ventures that have a significant probability of creating market power. Cooperatives may be exempt from the law in these areas and have generally not been challenged in them. As Assistant Attorney General Donald Turner stated, when merger "seems equivalent to the voluntary enrollment of new members" because at the time of merger "each member . . . is free to withdraw and to be reimbursed the value of his share . . . ," then merger would appear to be permitted. Creation of monopoly power by merger or joint venture appears to be legal for cooperatives, at least *de facto* if not *de jure*.

The Orders were codified in 1937 to provide: (*a*) orderly marketing, (*b*) an adequate supply of milk, and (*c*) an increase in farmers' incomes. These goals were not absolute but were to be balanced against "the public interest." They reflect the technological and economic conditions of that time and need to be reevaluated in the light of current conditions (Masson and Eisenstat; Alagia).

The milk markets of the 1930s differed substantially from today's markets. A prospective buyer could not phone a farmer, a cooperative, or a broker and expect them to deliver high quality milk over any distance. Coops

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This article represents the views of its authors and is not to be construed as representing the views of any agency of the United States Government.

were still forming; before pasteurization, a buyer had to know and have confidence in each source; many rural areas did not have phone systems; farms lacked refrigeration; trucks were slow and roads circuitous; and farmers did not have the technology to verify how much milk they sold or the butterfat it contained. Along with severely depressed farm income, these conditions led to localized and often unstable markets.

Today's technology and economic conditions would not produce market disorder as conceived in the 1930s. However, the U.S. Department of Agriculture (USDA) now treats "orderly marketing" as synonymous with "regulated marketing"; "disorderly" includes even desirable aspects of perfect competition (Dobson and Salathe).

Because the markets of the 1930s sometimes failed to supply enough milk of sufficient quality for fluid consumption, the Act was designed to assure that consumer demand for fluid milk was met. Again, as technology has shifted, so have USDA's definitions. Now USDA asserts a need for an adequate supply of milk for all uses (Masson, pp. 23–39). The Department dismisses the traditional indicators (USDA 1977, p. 29) which show massive surplus (Dobson and Buxton, pp. 8–11; Masson, pp. 23–39). And as will be seen, the demand for milk for all uses has been grossly distorted by the Orders.

The need to raise farmers' incomes through such programs should be reexamined now that the gap between average dairy farm income and average urban income has disappeared. If average dairy farmer income were equivalent to average urban income, then dollar subsidies would flow from poorer consumers to richer farmers. The income elasticity of demand for milk is close to zero, so the "tax on consumers" is a regressive poll tax, whereas the subsidy to farmers is proportional to farm size and wealth: the 3.3% largest dairy farms receive more subsidy dollars than the 44.8% smallest. Manchester shows that dairy farmers currently earn 40% more than their urban counterparts (even excluding capital gains), radically shifting the balance between the dairy farmer and the consumer (pp. 28–30). Even given a case for continued regulation, prices could be lowered significantly and still satisfy the first two goals. In this case the public interest must balance the farmer income goal against the consumer's welfare, a balance which has shifted radically over the years.

The Theory of Income Enhancement, Market Power, and Social Costs

In the 1930s Gaumnitz and Reed presented a model to show how monopolistic price discrimination could enhance dairy farmer income and rents when farmer supply could not be restricted. Price is raised for fluid or Class I uses of milk where marginal revenue is low, and the rest of the supply is dumped into Class II (butter, powder, ice cream, etc.) manufacturing uses where marginal revenue is higher. This principle underlies the Orders.

Price Discrimination and Income Enhancement

In unregulated competition a homogenous commodity will sell for a single price regardless of end use. This will be true even when the demand for the product is different for different uses. When a buyer uses a product for dissimilar purposes, the single price generally (though not universally) implies that marginal revenues differ between submarkets defined by use. Total revenue can be increased for any output by shifting product from a low to a high marginal revenue market. If this is accomplished, average revenue will be higher than it would have been under competition at all output levels. If each unit of sales shares these increased revenues equally, an average revenue curve is established above the demand (unregulated average revenue) curve. Monopoly power restricts the quantity of Class I milk. Because the higher average revenue induces an expansion in the supply of milk, the new equilibrium has both higher quantity and higher price unless the supply is infinitely elastic. Although farm profits return to zero, this will be due to rising Ricardian rents (Buxton; Ippolito and Masson, p. 50).

Social Costs of the System

This price discrimination raises price, *PI*, for Class I milk and suppresses price, *PII*, for Class II milk, thus raising social costs. Assume that at some current margin the Class I price exceeds the Class II price. Then assume that the Class I price is raised sufficiently that one fewer unit of Class I milk is purchased. One social effect is the lost value of that unit of milk in the Class I market, *PI*, net of the value of that unit of milk in its alternative Class II use, *PII*. Induced supply expansion is also

costly. Individual farmers are price takers, so the marginal cost of output expansion is equal to average revenue. The social cost of supply expansion is thus the average revenue or "blend price," Pb, times the induced change in supply, dQ_s, net of its value in use, the Class II price. Hence the marginal social cost of a unit of milk taken from Class I is $SC = (PI - PII) + (Pb - PII)\ dQ_s$.

These principles have been used to solve for the deadweight losses of the Orders and for transfers from consumers to farm rents by Ippolito and Masson; Buxton; Hammond, Buxton, Thraen; and others. Ippolito and Masson arrived at minimum bound estimates of approximately $25 to $30 million a year of social costs due to the deadweight losses. Other estimates have varied from a low of about $10 million.[1] In addition, regulatory expenditures amount to at least $34 million a year. Although the Orders raise farm income, they do not maximize farmer income. This leaves room for monopoly power. Regulated prices PI and PII yield average revenues of Pb through a mechanism by which buyers pay a government Market Administrator (MA) PI for all milk used for Class I, QI, and PII for Class II, QII. The MA "pools" all the revenues over the milk total, QT, and pays the price $Pb = (PI\ QI + PII\ QII)/QT$ to the farmers or their cooperatives.

Now assume coop A controls 100% of a market and, for simplicity, that PI and PII are parametric. The coop may increase revenues by charging a premium, D, above the regulated price PI. If these revenues were also collected and pooled by the MA, then QI would fall due to the higher price $PI + D$, and both QII and QT would rise. However the MA does not collect these revenues, so a coop can achieve premiums only on milk it sells as Class I. If a competitor makes a sale, only the competitor receives that premium revenue. In addition, both the coop and the competitor receive Pb from the MA.

In most markets some buyers only purchase Class II milk, while others purchase both Class I and Class II milk. The latter are called "fluid handlers." A coop ships truckloads of homogenous-commingled milk to fluid handlers who pay $PI + D$ for units put into Class I and PII for Class II. The coop receives $Pb + D$ for Class I and Pb for Class II, but each unit in the load was associated with a single marginal cost. This type of price discrimination requires market power in excess of the buyer's power. (Strictly speaking, D is actually the excess of any Class I premium over any Class II premium.) To countervail power means to offset power. Monopsonists restrict purchases, driving the supply price below the demand/marginal revenue product curve. Countervailing a monopsonist's power pushes price up to the demand curve but not above the supply curve and quantity increases to clear the market where demand equals supply/marginal cost. In contrast, raising D pushes price above marginal (opportunity) cost and decreases fluid handler purchases. Also, if D simply countervailed buying power then $Pb + D$ would be the competitive price (given regulation). Class II users would then be revealed as monopsonists.

Define U^k for the k^{th} seller as the proportion of k's milk, which is used in Class I, or k's "utilization rate." We now assume that a coop A has an intra-order competitor, C. The total market utilization rate is $U^m = S^a U^a + S^c U^c$ where S^k denotes k's market share and $S^a + S^c = 1$. If k has a cost of doing business of X^k per hundredweight (cwt), then the net return per cwt, r^k, of being a member of k is:

$$r^k = Pb + D^k U^k - X^k \qquad k = A, C.$$

Let us also assume that each handler sees a cost of doing business with group k as Y^k per cwt purchased. The handler's cost is $PI + D^k + Y^k$ for Class I and $P_{II} + Y^k$ for Class II. The handler's iso-cost between A and C is $D^a U^h + Y^a = D^c U^h + Y^c$ where U^h is the handler's utilization of Class I milk.

Now let us model competition. We shall initially assume that QI and QT are constant so U^m and Pb do not vary. Let us say that initially $S^a = 1$ but a group of members is considering agreeing to withdraw from A to compete. They will raise their income only if they achieve a D^c such that $D^c U^c - X^c > D^a U^a - X^a$. If this group needs to equilibrate costs to the handlers to make sales, they will not compete if:

$$D^a < [(X^c - X^a) + (Y^c - Y^a) U^c/U^h]/(U^c - U^a) = D^a{}_p.$$

This establishes the barrier to new competition or the "protected premium," $D^a{}_p$.

[1] Our study included all U.S. milk, including state orders, and assumed that the grade A price would exceed the grade B price by about $.30 in Eau Claire and more elsewhere. Other studies have looked only at Federal Orders and assumed a wider grade A differential. Also, Buxton assumes that supply is highly inelastic: .14. A low elasticity raises measured farmer rents but lowers measured social costs as dQ_s is smaller.

In a frictionless system $X^c = X^a$ and $Y^c = Y^a$, so competition is preferable to membership as long as $U^c > U^a$ may be achieved. D^a_p is sensitive to the X^k's, Y^k's, and U^a. If $U^c = U^h = 1$, then the protected premium is $D^a_p = [(X^c + Y^c) - (X^a + Y^a)]/(1 - U^a)$. If the numerator or "gross cost disadvantage" is \$.10, then D^a_p is \$1.00, \$.50, or \$.20 as U^a is .9, .7, and .5. A gross cost disadvantage of \$.20 would double D^a_p. Modest artificial impacts on the X^k's and Y^k's can radically alter D^a_p.

How Regulation Creates and Maintains Market Power

Part of the key to milk cooperative market power is operating in several milk markets. Coop A's revenue in any market is

$$R^a = \left[\frac{PI(QI^a + QI^c) + PII(QII^a + QII^c)}{QI^a + QII^a + QI^c + QII^c}\right] (QI^a + QII^a) + QI^a D^a,$$

so if a coop took a unit of Class II milk from Market 1 to Market 2, its marginal revenue would be

$$MR_2{}^a - MR_1{}^a = S_2{}^c U_2{}^m (PI_2 - PII) - S_1{}^c U_1{}^m (PI_1 - PII).$$

For example, if $S_1{}^a = 1$; $S_2{}^a = .75$; $X_1{}^a = X_2{}^a$; $(PI_1 - PII) = (PI_2 - PII) = \$2.00$; $U_1{}^m = U_2{}^m = .7$; and both markets were of equal size, then by moving 22% of the milk out of Market 1 into Market 2 the coop could "reblend" its revenues and continue to pay its original Market 1 producers the same net blend price, $r_1{}^a$, as before and pay its Market 2 producers \$.26 per hundredweight more than before. If there were no threat of competition in Market 1, the coop could hence artificially create an $X_2{}^a = -.26$ so even if $X_2{}^c = 0$, $(X_2{}^c - X_2{}^a) = .26$. Using an assumed $X^c = Y^a = Y^c = 0$ then Market 2, which without manipulation had no market protection, now has market protection, for $D_2{}^a < 60$. The members of C can increase their revenues by joining A! All other things being equal, a cooperative with a dominant share in one market has regulatory incentives to pool milk on markets where it has more competitors. This incentive is reduced, the more milk has to be physically shipped between the markets to effectuate this shift. For many market pairs, the necessary shipments are low. In some markets, if a coop ships milk from Market 1 to Market 2 for one or two days, the coop's milk subsequently would be pooled as Market 2 milk even if no further shipments to Market 2 take place.

Why do the regulations permit such pooling? Given price regulation, such pooling regulations are needed for efficiency. The cost of transporting milk is far higher than the cost of transporting Class II products. Given the seasonality of production, farmers located far from city centers needed to be encouraged to produce fluid grade milk so the cities would have enough milk during low production fall months. This encouragement took the form of granting them the blend price. If during the spring they had had to ship their Class II milk to the city to receive the blend price, that would have been an inefficient transport of milk for Class II use rather than Class II products. Guidelines were developed to decide which farmers needed to be encouraged to produce to fulfill the needs of these markets during the fall. USDA is faced with a quandary: the more it requires actual shipments to demonstrate backup potential, the less a market can be manipulated—but the less efficient the handling of the true backup supply.

Such cross-market pooling drives down the prices received by competitors of a multimarket dominant cooperative. As we have noted, reblending manipulates X^a and reduces the incentive to compete in markets where there is significant competition. Particularly in markets with traditionally high utilization rates, moderate changes in the X^a's reduce the incentive to undercut monopoly premiums substantially. The lower prices received by competitors are not reflected in lower consumer prices, but rather in power to charge even higher monopoly prices.

Even moderate manipulation of the pooling provisions can create large changes in D^a_p's. In recent testimony Associated Milk Producers, Inc. (AMPI) explained how they shift pooling in this fashion.[2] Baumer showed that high market shares lead, *ceteris paribus*, to higher intramarket utilization (i.e., pooling surplus elsewhere). (See also Masson, pp. 100–2.)

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[2] Testimony of AMPI's Joe E. Murphy and Kiefer Howard. Record, *In the Matter of Proposed Marketing Agreements and Orders Regulating the Handling of Milk in the Texas Marketing Areas.* USDA Docket No. A0-231-A45 et al., 7 Apr. 1977, Irving, Tex., pp. 602 (Murphy), 867 (Howard). See especially pp. 702, 786–90, 801, 879, 895–97, 907-8 and 912.

Before actions by USDA and the Department of Justice (DOJ), this type of manipulation was far more pronounced. Cross market-pooling was pursued to drive competitors out of markets, and was referred to as "pool loading."

An example is useful.[3] In 1967 AMPI started to load the Oklahoma pool, dropping U^m from an annual average of about 67% to 57% starting in September. While many farmers were driven into AMPI, part of the target group was able to use the order provisions to avoid regulation and the pool loading. In 1969, AMPI succeeded in voting an amendment to the order provisions which repooled these producers. In 1970, it pooled Class II milk from Iowa, Minnesota, and Wisconsin on the Order. By physically shipping one day's production to the market, the entire production of those farmers was pooled on Oklahoma for subsequent months even though it remained in its original geographic area. The utilization rate dropped to an annual average of 47% as AMPI "paper pooled" 36 million pounds a month in addition to its indigenous supply of 45 million pounds a month. This enabled AMPI to reblend well above the depressed market blend price. By September of 1971, only around 40 of more than 160 farmers remained as competitors.

In some cases, due to costs, prices, or market shares, changing market pooling to drive down competitors' prices was not profitable. In these cases, for the same reasons, regulation reduced the costs of predation. For instance, traditional north Texas milk could be pooled on south Texas simply by changing some computer cards in AMPI's accounting system. From 1971 through at least 1974, this technique decreased U^m by over 20%, cost AMPI about $30,000 a month, but took almost $40,000 a month of competitors' pool revenues.[4]

Flexible pooling comes from a need, given regulation, to promote efficiency. Although this flexibility is no longer manipulated in a predatory fashion, the moderate repooling flexibility inherent in the system helps protect monopoly premiums by reducing incentives to compete.

The order system protects market power in other ways. If competition has been eliminated (either by monopolization or by voluntary merger), the dominant coop must worry not only about intra-order competitors but also inter-order competitors. The order system reduces inter-order competition as well.

Consider the options available to a buyer facing a full supply, all-or-nothing contract demand from a dominant cooperative. If intra-order supplies are controlled by the coop, the buyer must look to other markets.

Sellers in other areas could sell milk directly to the buyer and become pooled on the buyer's market. Were they to do so, they would increase S^c and shift the balance of MR's across markets. The coop then has the same incentive to pool additional milk on that market. The competitor will receive the reduced price as it is now an intra-order competitor. The competitor might then be better off returning to its originating order. If it were to do so, the cooperative's power would be reestablished, the buyer having lost its supply. Also, provisions in an originating order may inhibit a return, leaving the sellers no defense against the lower price. Sellers may not be willing to take this chance.

Alternatively, a potential seller may buy and pool milk in its traditional market and then resell or "transfer" this milk to the buyer. USDA regulates such sales to keep sellers in one market from undercutting those in another, increasing transport costs and destroying the natural milk supply for that market. Hence they created a "tax" on such sales, which is lower if the receiving market has a shortage (i.e., a very high U^m). This was efficient because without monopoly power, milk transport between markets is inefficient unless there is a shortage. But monopolies take advantage of this tax. Consider a buyer who is purchasing both Class I and Class II milk. The buyer then desires more Class I milk, but this milk carries a premium of D^a, while less expensive milk is available in another market. The buyer then buys milk by a transfer from this other market. Part of the milk is then "down allocated," i.e., allocated "down" from Class I to Class II. The MA in the receiving market treats the increased Class I milk as having come from the dominant coop (not the outside) and the Class II milk as com-

[3] Sources for all examples using AMPI are cited in Eisenstat, Masson, and Roddy. *U.S.* v. *AMPI* was settled out of court, the authors were not subject to cross-examination, and AMPI does not admit to the allegations contained in this report. The reader should also be aware of the critique by Cook, Blakley, and Berry. However this critique does not examine evidence of intent (p. 1), which is the focus of the original report.

[4] USDA (1977, p. 32) claims credit for stopping pool loading in 1971. However some pool loading continued, in this case until 1974 (Masson, pp. 96–100).

ing from the outside. The buyer will receive a premium bill which is still high (it did not achieve the lower premium because of the down allocation) and it will pay into the pool the Class I price, raising the blend price received by the coop. (Additional transport absorption costs are inherent in down allocation as well.) Limitations on down allocation reduce it when U^m is high. This acts like a tax paid to the MA when buying out-of-market supplies.

Down allocation creates a barrier to entry for new intra-order competitors. If a market requires outside milk, the "tax" must be paid on it and the subsidy spread across all order farmers. Hence, for buyer k the cost of outside milk is $t(1 - S^k)$ per unit of milk, where t is the tax per unit. A proprietary buyer does not sell raw milk so it pays t per unit, a coop with 5% of the market $.95t$, and a coop with 85% only $.15t$. AMPI, for instance, had over 90% of the market in ten of its sixteen southern markets and over 70% in thirteen of them in 1973. Pointing to "large" inter-order flows of milk (1976), USDA says that down allocation does not create a barrier. (When U^m is high this may be true; however, U^m is not always high.) But because a dominant coop only pays a fraction of the tax paid by competitors, statistics showing inter-order milk movements are no gauge of inter-order barriers to entry unless all dominant cooperative movements are deducted.

A final source of outside competition used to be unregulated milk from the far north, M-W milk. Unregulated producers could not lose by pooling on an order because if the pool were loaded they could withdraw without cost. Prior to 1967 this milk could undercut premiums to draw higher blend prices. (Eisenstat, Masson, Roddy.)

In 1967, several cooperatives taxed their members to pay M-W producers not to ship milk unless asked by a contributor. This "standby pool" was said to be a contractual reserve supply needed to avoid having to pay up to $1.00 extra for outside milk in case of shortages. Shipment data and receipts show that these coops paid well over $5.00 extra per hundredweight for milk actually shipped ("reserve payments" over time plus actual point of shipment costs), and many paid far more.

The 1975 consent decree with AMPI substantially reduced the effectiveness of the standby pool. By that time, increased transport costs also had reduced the importance of this milk as a competitive force. Further, in 1976, USDA established a new milk order, order 68, for that previously unregulated area. The order provides for a power to require plants to ship to other areas when there are shortages but inhibits shipments otherwise.

Cooperative Exemption Far In Excess of That Intended

In the last decade some milk cooperatives held market power far in excess of countervailing levels. This cannot be rationalized on the basis of a public interest in raising depressed farmer income; it has been bolstered by the Orders, and it could have been avoided by jurisdiction over cooperative mergers and joint ventures.

AMPI was formed by a series of over ten major mergers starting in 1967. In the next three years AMPI merged with fifty-four additional coops. Some of these mergers were coerced; some were voluntary (Eisenstat, Masson, Roddy). Had the agglomeration been based on freedom of individual farmer membership, it would have succeeded only where there were efficiency gains. Because individual freedom of membership is inherent in the system, the cost to society of prohibiting large market-share mergers is far lower in cooperative ventures where members may leave less efficient coops than in proprietary ventures where less efficient firms may survive.

The growth of some dairy cooperatives in the last decade can be compared with the growth of firms like Standard Oil and U.S. Steel near the turn of the century. Like AMPI, Standard Oil mergers led to predatory and exclusionary practices. But the growth of U.S. Steel resulted in just as undesirable results, despite the lack of "bad acts." Because of the absence of bad acts, U.S. Steel was ruled innocent of monopolization despite the large market share it had acquired. U.S. Steel used its market power to charge higher prices than competitors for decades, letting its market share slowly erode. If it was as efficient as its competitors, it must have charged a monopoly price or it would not have lost its market share. If the U.S. Steel mergers created a firm with higher prices because it was less efficient than its competitors, the conclusions are even more negative. Although economic theory shows that this pricing behavior requires monopoly power, U.S. Steel was judged not to have monopolized in part because its market

share was declining! A similar conclusion might be reached by a court today.

Today, to ascend to a dominant position, a corporation must be more efficient than its competitors. We are protected by the Clayton Act from corporations merging to positions of market power like U.S. Steel. We are not so protected against mergers of agricultural cooperatives. Given the current Capper-Volstead Act interpretation, nothing prevents a cooperative from merging to monopoly, pricing high until its market power dwindles, and merging to monopoly again!

To analyze the costs of the status quo we need to examine how it has worked. By 1967–68, hundreds of mergers and federation/joint ventures had solidified milk cooperative market power. Large monopoly premiums were established by late 1967. About this time some of these coops started to use predatory and exclusionary practices to further their power. One of these practices was pool loading, which USDA watched with increasing alarm. As the intensity of pool loading climaxed in 1971, USDA took action to decrease incentives to load the pools in sixteen affected markets, halting it in some, only decreasing it in others (Masson, pp. 96–102). USDA concern focused on the manipulation of the Orders but was not critical of the prices that resulted (USDA 1976).

In 1972, DOJ filed suit against AMPI, alleging the use of predatory and exclusionary acts and practices. The case was settled by a consent judgment in 1975, and DOJ has been monitoring compliance since then.

What is the evidence that there was market power? Different prices for Class I and Class II commingled milk (i.e., milk with a single cost) require market power. Several studies have shown that milk premiums are significantly related to dominant cooperative market share (Masson, pp. 68–76). Baumer has traced the effect of dominant cooperative market share on the retail price of milk. He finds an effect of 7¢–10¢ per gallon, which far outweighs the impact of supermarket concentration. This power has declined because of antitrust action. The market share premium studies generally lose significance starting with 1975 data, as would be expected if the consent decree had substantially reduced AMPI's market power.[5]

Using the same method we used for regulation, we may estimate the social costs of monopoly pricing. If we assume that all Class I milk had premiums similar to those in reported markets, then we may calculate the effects of this additional price elevation. (We assumed all reported $D^a > \$.05$ was because of market power.) We arrive at additional deadweight losses of \$31 million for 1973. We also calculated that high costs of maintaining market power eroded about three-fourths of AMPI's premium revenue.[6] Some of these costs were due to inefficient transport or other social costs, others were transfers. To be conservative, we assumed that one-quarter of national Class I premium revenue was eroded into social costs. This yielded an additional social cost of \$40 million. The total estimate of \$71 million per annum probably is representative of annual costs from late 1967 to the consent decree of 1975. As the decree reduced AMPI's market power it should have lowered other coops' power as well. AMPI stood in a key area for determining the geographic structure of all milk prices and other coops' market power also came in part from federation with AMPI.

After signing the decree, AMPI started charging a stated premium net of "competitive credits" in its southern region (Fones, Hall, Masson, p. 295, n. 1). We have complete data on actual premiums for only one AMPI southern market. We used a time-series test with Cochran-Orcutt adjustment of the form,

$$D^a = a_0 + a_1 U^m + a_2 PI + a_3 LIII + a_4 T + a_5 F + a_6 C,$$

where $LIII$ is a dummy indicating lifting of Phase III price controls, T is a cost of fuel index, to proxy transport costs, F is an index of dairy feed costs, and C is a dummy variable equal to one after the consent decree. We would hypothesize from the model presented above that $a_1 > 0$, market power increases with the market utilization rate, $a_2 < 0$, Class I price including premium is generally read-

[5] USDA (1976, pp. 53, 63–75) implies that no market power exists unless price exceeds "the cost of alternative supplies." Clearly, such a test can tell only if price exceeds a limit price, not whether the competitive price is the limit price. The USDA authors also cite significant t-values as insignificant by misapplying a two-tailed t-test. Significance declines from over 95% to very low levels after mid-1975 (pp. 66–67). As AMPI lost power, so would other coops, because AMPI was in a key position in the structure of milk prices and a key member of the standby pool. In 1975 the t-values drop for all standby pool member cooperatives (p. 73), and the values for AMPI fall relative to most other coops (Baumer, p. 75).

[6] Because of an arithmetic error, we had stated earlier that virtually all of this revenue was eroded.

justed less frequently than PI, $a_3 > 0$, Phase III seriously limited AMPI's premium charging abilities, $a_4 > 0$, transport cost increases raise market insulation, $a_5 > 0$; as feed costs increase, farmer militancy strengthens bargaining; and $a_6 < 0$, the AMPI consent decree was effective. The results using Cochran-Orcutt adjustments were

$$\begin{aligned} D = -.18 &+ 1.74U^m - .32PI + .82LIII \\ (0.31) &\;\; (3.62) \qquad (5.70) \quad (5.70) \\ &+ .68T + .007F - .53C. \\ &\;\; (1.99) \quad (2.26) \quad (4.47) \end{aligned}$$

(t-values in parentheses)

All t-values except for the constant are significant at the 99% level. C is significant at the 99.9% level.

The AMPI consent decree is working. Given relatively higher utilization rates and transport costs, the predicted premium of the last twelve months of data (into early 1978) was \$.94 without the decree and only \$.42 with the decree. Given a subsequent contempt of court action, higher transport costs, and the establishment of Order 68, these are strong results for less than three years under the decree.

The litigation based on the Sherman Act started about four years after the monopoly was established, and the decree was entered about three years later. Thus, ten years after the monopoly was established, about half its power has been dissipated. This may demonstrate the effectiveness of the Sherman Act given a monopoly; but there need not have been a monopoly, had anticompetitive mergers and joint ventures been limited for cooperatives as for corporations.

Conclusion

Mergers in the late 1960s and early 1970s led to large milk cooperative monopolies. These monopolies have been able to manipulate federal regulation to advantage over competing farmers and regulation continues to protect established power. A social cost analysis model shows that this power cost society at least \$70 million a year prior to antitrust action.

Had cooperative merger been covered by the Clayton Act, this massive degree of power would not have emerged. Without the predatory and exclusionary acts of some coops this power might have been unreachable under the antitrust laws. Without antitrust action, market power would be slowly eroded by monopoly pricing. However, it could be reestablished by use of merger.

Clearly, the antitrust market share standards used to challenge corporate mergers or joint ventures are too stringent for evaluating the anticompetitive impact of cooperative mergers or marketing agreements. But like corporations, cooperatives must be prevented from merger or joint venture where "the effect may be substantially to lessen competition" if society is to be protected from power which far exceeds that originally intended by the Capper-Volstead Act.

References

Alagia, D. Paul. "Federal Milk Market Order Regulations: A Defense." *S. Dakota Law Rev.* 24(1979):592–606.

Baumer, David. "Undue Price Enhancement By Dairy Cooperatives." Mimeographed. North Carolina State University-Raleigh, 1979.

Buxton, Boyd. "Welfare Implications of Alternative Classified Pricing Policies for Milk." *Amer. J. Agr. Econ.* 59(1977):525–29.

Cook, Hugh, Leo Blakley, and Calvin Berry. *Review of Eisenstat, Philip, Robert T. Masson, and David Roddy "An Economic Analysis of the Associated Milk Producers, Inc. Monopoly."* Agr. Res. Bull. R2790, University of Wisconsin, Jan. 1976.

Dobson, William, and Boyd Buxton. *Analysis of the Effects of Federal Milk Orders on the Economic Performance of U.S. Milk Markets,* Agr. Res. Bull. R2897, University of Wisconsin, 1977.

Dobson, William, and Lawrence Salathe. "The Effects of Federal Milk Orders on the Economic Performance of U.S. Milk Markets." *Amer. J. Agr. Econ.* 61(1979):213–17.

Eisenstat, Philip, Robert Masson, and David Roddy. *An Economic Analysis of the Associated Milk Producers, Inc. Monopoly.* Filed with the court in *U.S.* v. *AMPI*, 394 F. Supp. 29 (W.D. Mo. 1975), aff'd 534 F.2d 113 (8th Cir. 1976).

Fones, Roger, Janet Hall, and Robert Masson. *Milk Marketing.* Washington, D.C.: A Report of the U.S. Department of Justice to the Task Group on Antitrust Immunities, Jan. 1977.

Gaumnitz, E., and O. Reed. *Some Problems Involved in Establishing Milk Prices.* Washington, D.C.: U.S. Department of Agriculture, Sep. 1937.

Hammond, Jerome, Boyd Buxton, and Cameron Thraen. *Potential Impacts of Reconstituted Milk on Regional Prices, Utilization and Production.* University of Minnesota Agr. Exp. Sta. Bull. 529, 1979.

Ippolito, Richard, and Robert Masson. "The Social Cost of Government Regulation of Milk." *J. Law and Econ.* 21(1978):33–65.

Manchester, Alden. *Dairy Price Policy: Setting, Problems, Alternatives.* Washington, D.C.: USDA ESCS, Agr. Econ. Rep. 402, 1978.

Masson, Robert. *Response to the USDA Comments on the Department of Justice Report on Milk Marketing.* Washington, D.C.: U.S. Department of Justice, Oct. 1978.

Masson, Robert, and Philip Eisenstat. "The Pricing Policies and Goals of Federal Milk Order Regulations: Time for Reevaluation." *S. Dakota Law Rev.* 23(Spring 1978):662–97.

National Commission for the Review of Antitrust Laws and Procedures. *Report to the President and the Attorney General.* Washington, D.C., Jan. 1979.

National Committee to Study the Antitrust Laws. *Report to the Attorney General.* Washington, D.C., 1955 (Supp. 1968).

Turner, Donald. *Agricultural Cooperatives and the Antitrust Laws.* Washington, D.C.: U.S. Department of Justice, 1966.

U.S. Department of Agriculture. *The Question of Undue Price Enhancement by Milk Cooperatives.* Washington, D.C.: Capper-Volstead Committee, Dec. 1976.

U.S. Department of Agriculture. *U.S. Department of Agriculture Comments on the Department of Justice Report on Milk Marketing.* Washington, D.C.: Office of the Secretary of Agriculture, May 1977.

An Appraisal of the U.S. Government's Role in Milk Pricing

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The U.S. Department of Agriculture administers two major programs that greatly influence the price and other terms of trade for milk and dairy products. These are the Dairy Price Support Program and the Federal Milk Marketing Program. Both originated out of the social distress of the 1930s and have continued in modified form up to the present.

Throughout their history these two programs have been the subject of much professional inquiry and evaluation. Until the early 1970s, the inquiry centered on methods for achieving the perceived goals of the program. Seldom were the goals themselves brought into question.

All that has now changed. I think the change began with the formation in the late 1960s of several massive (by former standards) dairy cooperatives through merger of scores of smaller organizations. These new organizations said and did things that proprietary firms and the general public were unaccustomed to hearing and seeing in the producer-organized sector of the agricultural economy. They boasted of market power. They charged "premium" prices for raw milk. They amassed and spent large political funds. They engaged in allegedly predatory practices. The activities of these organizations gained much public attention, and soon the Cost of Living Council, the Justice Department, the Federal Trade Commission, and consumer groups began focusing on these large dairy cooperatives, their activities, and the institutions under which they operated (see Fones, Hall, Masson, for example). Dairy institutions of all kinds were and continue to be subjected to close scrutiny. Primary among these were the antitrust exemptions provided to cooperatives in the Capper-Volstead Act, the Dairy Price Support Program, and the Federal Milk Marketing Order Program. The questions now go to the foundations of these institutions, more than to the mechanisms employed. Fundamental purposes and goals are being challenged, and clearly the challengers hold the initiative. The topics under consideration at this session illustrate the new thrust of inquiry. One paper deals with the welfare impacts of milk orders and the antitrust immunities for cooperatives, and another deals with the welfare costs caused by regulation of dairy markets. I anticipate that the authors will conclude that the three institutions under consideration have negative welfare impacts. It seems almost trivial to say that nearly all institutions, dairy or not, create market distortions relative to the competitive norm, and thus have negative welfare impacts.

The assignment for this paper is to appraise the government's role in milk pricing. I am not offering a sophisticated technical analysis. Instead, I am offering my evaluation of federal dairy programs from the perspective of a major dairy industry participant. In doing so, I expect to recite much conventional dairy dogma and to run the risk of having my remarks dismissed as tainted or naive. Nevertheless, I think that the pedestrian view of the world merits consideration, and that we, as economic practitioners, must take into account the general level of satisfaction with the institutions we examine.

I plan to proceed with a brief description of federal dairy programs and then comment on specific issues that have arisen in the discussion of their merits.

The Dairy Price Support Program

The Dairy Price Support Program is authorized by the Agricultural Act of 1949 (7 U.S.C. 1466). Under this authority, the Secretary of Agriculture is directed to support the price of milk at a level between 75% to 90% of parity as he "determines necessary in order to assure an adequate supply, reflect changes in the cost of production and assure a level of

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farm income to maintain productive capacity sufficient to meet future needs." In practice, the Secretary establishes a support price for manufacturing milk only and seeks to achieve that national average price by offering to buy butter, cheddar cheese, and nonfat dry milk at fixed prices. The Secretary does not regulate the prices actually paid by milk processors to dairy farmers. He relies on competitive forces in the manufacturing milk market to insure that processors pay the intended support price, on the average.

The Secretary has been largely successful in achieving the intended level of support. The national average price for manufacturing milk averaged below the support price in only three marketing years between 1949 and 1978 (ASCS, p. 52, ESCS, p. 10).

The administrative discretion of where to set the support price between 75% and 90% of parity is quite wide. It represented 82¢ per hundredweight in 1970 and represents more than $2.00 per hundredweight today. Each year a considerable dispute arises as to the appropriate level of support. Producer groups are suspicious of the anti-inflation talk of recent administrations and have secured from Congress a guarantee of at least 80% of parity through 1981.

A great number of economic considerations enter the deliberations as to the appropriate level of support. Primary among them are the level of government stocks of dairy products relative to disposal opportunities, and the anticipated government costs associated with different levels of support. However, in the final analysis, the decision is political.

Some of the current issues relating to the Dairy Price Support Program are: (*a*) Is there a continuing need to protect the prices and incomes of dairy farmers with a Dairy Price Support Program? (*b*) Is it reasonable to maintain the parity formula for supporting milk prices? (*c*) Does the Price Support Program create unreasonably high milk and dairy product prices?

Continuing Need for the Dairy Price Support Program

Both supply and demand elasticities in the dairy sector are presumed to be inelastic.[1] If we accept this premise, then the industry is subject to wild fluctuations in price to achieve relatively minor changes in quantities produced or consumed. From the producer standpoint at least, this represents an undesirable state of affairs.

Volatile prices bring about more rapid adjustments than do stable prices. However, these adjustments do not come free of cost. Because dairying involves substantial investments in specialized equipment and facilities, supply adjustments are accomplished by abandoning some of the sunk capital. The risk associated with investments in dairying would be higher in a volatile price environment, and fewer producers would engage in milk production.

Some form of price and income protection, then, has the benefit of reducing risk for producers and encouraging a higher level of production at any given price. Consumers benefit from the relative abundance.

Although elementary economic analysis neglects the issue, consumers also express an interest in stable prices. The rapid rises in beef prices in 1973 and 1978–79 could be traced to competitive economic forces, but consumers complained bitterly. Apparently, consumers develop rather stable purchase patterns and resent their disruption by intermittent high prices. The strong public sentiment in favor of price controls administered by the government is another expression of consumer preference for stability.

From a broader public interest view, we could argue that volatile prices are good. The greater the price variation, the more rapidly needed quantity adjustments take place. For milk producers this means "survival of the fittest," and only the most progressive and efficient remain in the industry. It is not clear, however, that the cost savings incurred by weeding out the inefficient would offset the cost of abandoned capital.

Politically, programs that provide price stability seem acceptable to producers and consumers. However, I doubt that both producers and consumers are interested in the same level of price stability. Producers seek a price that will provide competitive returns to resources and a little more, if feasible. Consumers want the lowest price commensurate with abundance.

[1] Gruebele and Babb both accept elasticities of supply of less than 0.14, fluid demand elasticities of less than −.20, and manufactured demand elasticities of less than −.46 in their analyses of federal dairy programs. Their familiarity with the literature is more complete than mine.

We now have the Dairy Price Support Program which certainly has the potential for stabilizing prices, and for stabilizing them at levels that will satisfy either producers or consumers, or neither.

Maximum stability probably can be achieved by setting support prices for milk slightly above expected market-clearing levels. Such a price level would attract a small surplus to be purchased by the government. It also would assure an abundant commercial supply of milk and dairy products, and that short-run supply aberrations would not cause sharp retail price adjustments. While producers might not consider such a support price to be adequate, they would benefit from great price and income security.

It appears that over time the administration of the program has shifted so that it attracts smaller and smaller surpluses. See table 1. The percentage of milkfat and nonfat solids marketings acquired by the government under the Dairy Price Support Program has dropped dramatically from the early 1960s to the late 1970s. I think this change represents a decline in producer influence over the program. There is today much less attention paid to the income needs of dairymen and much more attention given to the level of consumer prices and government costs. Very simply, the political tolerance for a high support price for milk that will satisfy dairymen, but will also drive up consumer prices and government expenditures, is much reduced. For example, government costs under the Dairy Price Support Program reached an all-time high of $714 million in the 1976–77 marketing year, and there was much concern about the need, reasonableness, and justification for such an expensive program. However, if the 1962 volume of purchases were valued at the 1 April 1977 purchase prices, the cost would have been more than double the actual 1976–77 costs.

Table 1. Percentage of National Marketings of Milkfat and Nonfat Solids from the Commercial Market by Programs of the U.S. Department of Agriculture during Five-Year Periods, 1949–68

	USDA Removals as a Percentage of Marketings	
5-Year Period	Milkfat	Nonfat Solids
1949–53	2.76	3.84
1954–58	5.28	8.76
1959–63	5.70	11.18
1964–68	4.68	7.92
1969–73	4.62	3.66
1974–78	2.38	3.28

Source: *Dairy Situation*, DS-374, p. 24.

I see a danger in this trend toward administering the program in a manner intended to minimize short-run consumer price impacts and government expenditures. Such a course of action would be tantamount to abandoning the program and the worthy goals of "stability," "adequate supply," and "reasonable prices." I would state emphatically that we have a continuing need for the Dairy Price Support Program to retain the productive capacity of the dairy industry and to gain maximum assurance of an abundance of milk and dairy products at stable prices.

Should the Parity Formula Be Retained?

The parity index has been the primary adjustment factor in calculating the support price for milk. This aspect of the Dairy Price Support Program is under attack and alternatives have been proposed (Special Dairy Policy Advisory Committee, pp. 32–46). The basic arguments against the parity index are that it is out-of-date, that it is not responsive to the cost experience of dairy farmers, and that it is out of harmony with the methods used to support the prices of feed grains, food grains, and soybeans.

The basis of the parity index is old. It was created in the 1930s using data from 1910–14. It accurately reflects changes in specific input prices, but it does not take into account changes in technology, improved productivity, or increased scale of operation in American agriculture. I do not think it matters if the index has a long history. It does reflect the long-run movement of input and consumer prices, and thus does reflect a large component of the economic environment faced by farmers. It tracks the general price level reasonably well. Compared to the alternatives of a dairy-specific parity index or a cost of production index, the parity index is more stable.

The parity index does not determine the support price for milk. It is the mover that determines the bounds of the administrative decision as to where to set the support price for milk. The alternatives—the dairy-specific parity index, which would weight input prices in proportion to their use in the dairy enter-

prise, and the cost-of-production index—would serve the same purpose. They would simply establish the bounds for administrative discretion, and would not set any prices.

Changes in technology, input mix, productivity, and scale of operation do not argue against the parity index. They simply say that a lower percentage of parity in the present would provide the same net income for agriculture that a higher percentage of parity would have provided in the past. Offsetting this argument for income support at a lower percentage of parity is the increasing income needs of farmers to retain comparative standards of living relative to the nonfarm sector.

The question should not be "Is the parity formula appropriate?" Rather, it should be, "What percentage of parity is appropriate?"

I see little relevance in the argument for harmonizing the price support calculations for milk with the price support calculations for other commodities. The real issues are workability and acceptability. Variations in the supply of milk are much smaller than variations in the supply of field crops. Thus, a simple price support and purchase program may work well for milk, but not for food and feed grains. The greater the variations in supply that are not responsive to price, the greater the complexity of managing the supply in a way that stabilizes prices and incomes for producers.

The actual price at which commodities are supported is a political decision within the range of flexibility provided by law. It matters little whether the price target is to be achieved through government offers to purchase or through deficiency payments. What does matter is the cost and complexity experienced by the government by doing it one way or another. In the case of milk, there is an extra administrative burden associated with purchasing, storing, and disposing of dairy products, but government costs are small compared to a deficiency payment program.

It is not exactly correct that target prices are based on cost of production, and thus offer greater protection for producers. In the long run, target prices are set at levels that will keep government costs within acceptable bounds. It may be politically convenient at times to relate target prices to cost of production, but there is no iron rule tying the two together.

I believe the arguments for substituting an alternative mover for the parity index is a subterfuge to expand downward the range in which the support price can be set, opening the opportunity for lower support prices. The Special Dairy Policy Advisory Committee estimates lower milk prices through 1981 using either alternative to the parity index.

Expanding downward the range within which the support price may be set administratively will not assure a lower support price. If the goals of price stability and supply adequacy are pursued equally under the three alternatives, the result should be the same, except that greater inherent volatility would be introduced by the dairy-specific parity index or the cost-of-production index.

I see no need nor any desirability for abandoning the present dairy price support calculation using the parity index as a mover. If the support price attracts unacceptable surpluses of dairy products, it is a problem resulting from the administrative choices made within the range of flexibility provided, and not a problem resulting from the use of the parity index as part of the calculation.

Does the Dairy Price Support Program Enhance Consumer Prices?

The trivial, short-run answer to this question is, yes. Any time the government purchases dairy products at the support purchase price, it means that the commercial market will not clear at those prices. Wholesale and retail prices for dairy products would be lower if the government suddenly withdrew from the market.

Gruebele estimates that "During 1950–1975, the elimination of the price support program for dairy products would have been likely to reduce the average price for milk by 7 percent and milk production by 1.8 percent. If price supports were removed, milk prices probably would be 2.8 percent lower and production 0.8 percent lower between 1976 and 1980 than with price supports" (Gruebele, p. 30).

The long-run question is more difficult. Without a price-stabilizing, price-support program, the economic risk of milk production would increase, leading to reduced milk production at any given price. Also, the increased volatility of consumer prices might alter consumption patterns in unpredictable ways.

It is an unavoidable consequence of a price support program designed to increase price stability that at some times commercial prices will be above market clearing levels. If there is

to be a program with any effect, then it will have short-run, price-enhancing effects. The degree of price enhancement is produced not by the existence of the program, but by the administrative choices made within the available range of flexibility. For example, the price-enhancing effects of the Dairy Price Support Program probably would have been less if the support price had been fixed at a lower level of support in the past.

In the future, we can choose the amount of price enhancement provided by the Dairy Price Support Program. I do not think it will be great. Producer arguments for price and income enhancement are likely to be overridden by concerns about inflation and the status of the federal budget.

Federal Milk-Marketing Order Program

Federal milk-marketing orders are authorized by the Agricultural Marketing Agreement Act of 1937, but trace their origin to the Agricultural Adjustment Act of 1933. The objectives of Congress were to "establish, as the prices to farmers, parity prices . . . protect the interest of consumers by . . . gradual correction of . . . current prices," and to "establish and maintain such orderly marketing conditions . . . as will provide, in the interests of producers and consumers, an orderly flow of the supply . . . to avoid unreasonable fluctuations in supplies and prices." (7 U.S.C. 602).

Federal milk-marketing orders regulate milk handlers disposing of packaged fluid milk products within specifically defined geographic areas. There are forty-seven milk-marketing orders now in effect, although at one time there were eighty-two. However, the scope of regulation has expanded to the point where 80% of U.S. Grade A milk marketings are regulated under federal milk-marketing orders.

The fundamental structures of federal milk-marketing orders are (*a*) classification of milk according to use, (*b*) establishment of uniform minimum prices for milk used in each class, (*c*) a method of distributing the proceeds for milk in all uses to producers and associations of producers.

Federal milk orders and amendments are adopted following a long administrative procedure, and approval by the milk producers who are affected by the order. The most important part of the administrative process is the public hearing at which interested parties offer facts and arguments for or against specific proposal. In the past, most disputes over federal milk orders and their provisions were resolved through the hearing process. In recent years we see a greater political challenge to the order system than we have had in the past and less reliance on the administrative wisdom of the Secretary of Agriculture.

Current issues with respect to federal milk-marketing orders include (*a*) Is classified pricing necessary? (*b*) Are Class I prices too high? (*c*) Are Class I prices too low? (*d*) Do federal milk orders enhance the market power of dairy cooperatives?

Is Classified Pricing Necessary?

The Agricultural Marketing Agreement Act of 1937 directs that federal milk orders provide for the "classifying [of] milk in accordance with the form in which or the purpose for which it is used, and fixing, or providing a method for fixing, minimum prices for each such use classification which all handlers shall pay . . ." [7 U.S.C. 608c (5) (A)].

Most orders provide for three classes of use. Class I milk is that milk disposed of as packaged fluid milk products. Class II milk is milk disposed of as packaged fluid cream or used to produce cottage cheese, frozen desserts, and a variety of "soft" manufactured dairy products. Class III milk is milk used to produce "hard" manufactured dairy products such as cheese, butter, and dry milk products.

Prices for all three classes of use are established on the basis of the Minnesota-Wisconsin manufacturing milk price. The Class I price is the Minnesota-Wisconsin price for the second preceding month, plus a Class I differential. The differential ranges from a low of $1.12 at Minneapolis under the Upper Midwest order to a high of $3.15 at Miami under the Southeastern Florida order. The Class II price is the Minnesota-Wisconsin price, plus 10¢, and the Class III price is the Minnesota-Wisconsin price for the month.

Classified pricing means different prices for different uses or "markets" for milk. Some see classified pricing as a form of price discrimination designed to increase average revenue above the competitive norm (Masson, Masson, Harris). It is argued that such price discrimination results in high social cost and large transfers of income from consumers to producers.

Classified pricing does not conform to the competitive norm. Neither does the oligopsonistic form of market organization that characterized many fluid milk markets prior to the adoption of federal milk markets. It is probable that the price-enhancing effects of classified pricing brought producer prices closer to the competitive norm than before. I believe that classified pricing is a useful device that helps insure the smooth functioning of the fluid milk market, and that consumers need for fluid milk could not be met without classified pricing.

It costs more to produce Grade A milk, which must meet strict production and sanitation requirements, than it does to produce manufacturing milk. Therefore, Grade A dairy farmers must be paid a higher price than manufacturing milk producers in order to maintain adequate Grade A production.

If all Grade A milk could be bottled and sold in fluid form, one price for Grade A milk would solve the problem. But not all Grade A milk can find a Class I or fluid market outlet. Milk production is reasonably steady on a day-to-day basis, but varies widely on a seasonal basis. The variations in demand are far out of harmony with the variations in milk production. Fresh fluid milk cannot be stored long enough to cover these variations, so if sufficient Grade A milk is available on the day and in the season when the demand for fluid milk is greatest, then too much Grade A milk will be available at all other times.

What happens to this extra or "reserve" Grade A milk if it is not needed for bottling? It is processed into manufactured dairy products that compete on even terms with similar products made from manufacturing grade milk. A milk manufacturer could not accept reserve Grade A milk for processing if the price is higher than his competitors pay for manufacturing grade milk. So it is apparent that the supply of Grade A milk cannot clear the market at a price higher than the value of manufacturing milk. But if greater returns are needed to maintain a steady supply of Grade A milk, then there is only one way to get those returns, and that is through a differentiated Class I price that is high enough to compensate farmers for both the extra costs of producing Grade A milk, and for the losses they incur in disposing of reserve supplies in the manufacturing milk market.

Classified pricing is necessary to get Grade A milk produced on the farm. Classified pricing is also necessary to get the Grade A milk moved from the farm to the consuming center. A plant operator receiving milk in the country has the choice of processing the milk on the premises and paying the Class III price for it, or of shipping the milk to a consuming center and paying the Class I price. Clearly, he will not choose to ship unless the Class I price at the consuming center covers his local Class I cost plus the hauling cost. Milk is expensive to haul because it is bulky and perishable and must be transported in temperature-controlled, sanitary equipment.

The high cost of moving milk accounts for most of the variation in Class I prices around the nation. Milk must move out of the upper Midwest to satisfy the needs of consumers in the South and East. A difference in Class I prices is necessary to pay the freight.

I believe that the Grade A milk-marketing system cannot operate satisfactorily without classified pricing. A dependable supply of Grade A would not be produced; the Grade A market would not clear reserve supplies; and fluid milk would not move from production areas to consuming centers.

Are Class I Prices Too High?

If classified pricing is necessary to attract Grade A milk to fluid markets, how high should Class I prices be to accomplish this purpose? There is no clear-cut answer, but several analysts argue that the present structure of Class I prices is higher than necessary to attract an adequate supply (see Dobson and Buxton, for example).

The most difficult aspect of this issue is the definition of an "adequate" supply. Adequate supply for a fluid milk market requires that sufficient Grade A milk be available to meet fluid demand at all times. A reserve supply of Grade A milk is necessary to cover the variations in production and processing demand. In addition, not all the Grade A milk received at a bottling plant can be used as Class I milk because of plant loss, inventory variation, route returns, and the fact that the fat test of finished products is lower than the fat test of producer milk.

How much "reserve" Grade A milk is needed to cover all these variations? Conventional wisdom has held that a 20% annual reserve should be adequate. USDA adopted this figure in its 1964 decision (29 F.R. 9110-9125)

implementing the changes required by the Supreme Court in the Lehigh decision (*Lehigh Valley Cooperative Farms, Inc. et al.* vs. *United States et al.*, 4 June 1962), and it carries forward in the present provisions of federal milk orders.

Dobson and Buxton used a more sophisticated approach and adopted a 37% reserve allowance in their analysis (Dobson and Buxton, p. 9). This included an allowance of 12% to cover seasonal variations plus 25% to cover variations in daily demand as well as unavoidable Class II and Class III uses in bottling plants. I believe these estimates are reasonable if viewed as minimum operating reserves in a highly coordinated system of markets.

There is a further justification for maintaining a reserve of Grade A milk in federal milk order pools over and above operating requirements. This is the need to maintain blend price alignment among markets. The so-called "blend" price is the weighted average of the class prices in a federal order market and is the minimum price to be paid producers and associations of producers.

The basic supply of producer milk associated with any federal order market is attracted to it by the blend price. Producer milk can be transported from the farm to markets as much as 500 miles away, so dairymen and their marketing associations have a wide range of choice as to which federal order pool to participate in. Their logical choice is the pool rendering the highest blend price, net of transportation costs. Less milk will be pooled in a market with a relatively low farm-point blend price and more milk will be pooled in a market with a relatively high farm-point blend price. The natural result of producers shifting to more attractive markets will be a structure of blend prices that reflect differences in transportation costs from production areas to consuming centers.

To achieve a price structure of this sort, there must be differences in the percentage of producer milk used in Class I, as well as differences in Class I prices. For example, consider the blend price relationship that should exist between Minneapolis and Kansas City if producer milk is to flow from the former to the latter. The two cities are about 450 miles apart. If transportation costs are 15¢ per hundredweight per hundred miles, then the blend prices in the two markets should differ by 67.5¢ (15¢ × 4.5). In 1978, the Class I price averaged $11.03 per hundredweight in Kansas City and $10.43 in Minneapolis. The blend price in Kansas City averaged $10.38 in 1978, so a properly aligned blend price for Minneapolis would be $9.705 ($10.38–$.675). To achieve that blend price in Minneapolis, the upper Midwest market should experience no more than a 13% Class I utilization. Thus, the reserve requirement for the upper Midwest market amounts to 87%.

Following this analysis, reserve requirements for the upper Midwest market reach infinity if transportation costs exceed 18¢ per hundredweight. Transportation costs do exceed 18¢ per hundredweight, so an alternative to associating an infinite quantity of Grade A milk with the upper Midwest market is to increase effective Class I and blend prices in Kansas City and other markets outside the upper Midwest. This has been accomplished to some degree through the bargaining activities of dairy cooperatives.

The important point is that reserve requirements needed to achieve a workable blend price structure for a system of markets can easily exceed the reserve required to cover variations in milk supply and fluid demand. This leaves open the question of whether existing Class I prices are higher than necessary to attract an adequate supply. I doubt that they are.

Are Class I Prices Too Low?

We can suspect from the previous discussion that Class I prices may be too low to attract sufficient milk to align properly blend prices. Higher Class I prices and higher utilization of producer milk in Class I in markets outside the upper Midwest would facilitate improved blend price alignment, and reduce the necessity of associating increased volumes of Grade A milk with the system of federal order pools.

While relative blend prices are important in determining which producer milk is associated with which federal order pools, relative Class I prices largely determine the movement of plant milk between federal order markets. Under present provisions, a load of milk transferred from one federal order market to another is classified on the basis of the utilization of the receiving plant or the receiving market, whichever represents the lower Class I use. The consequence of this provision is that only part of the load of milk is assigned to Class I, and the remainder is assigned to Class III or Class II. Class II and Class III prices are the

same in most federal order markets, so there is no price difference to compensate for the cost of transportation. There is normally a difference in Class I prices to compensate in part for the cost of transporting milk between two markets.

If Class I prices are to be aligned to encourage the movement of plant milk from low utilization markets to high utilization markets, then the difference in Class I prices must exceed the cost of transportation. For example, if milk is to be shipped from a low price market to a high price market with an 80% Class I utilization, then the Class I price difference should be 125% of the hauling cost. Hauling costs are incurred on 100% of the load, while the difference in Class I prices is paid on only 80% of the load.

Consider the magnitude of Class I price changes needed to facilitate the inter-order movement of plant milk with the present transfer provisions. During 1978, Class I utilization in the Kansas City market reached a peak for the year in November at 63%. With a hauling cost of 25¢ per hundredweight per hundred miles, a Class I price difference of $1.79 would be necessary to move plant milk from Minneapolis to Kansas City (450 miles × $.0025 hauling cost per mile ÷ 63% Class I utilization). The actual difference in Class I prices is only 62¢, so a Class I price increase of $1.17 may be in order for Kansas City. With the same hauling cost, a Class I price difference of $3.50 would be required to move plant milk from Chicago to Miami in June 1978 (1,329 miles × $.0025 hauling cost per mile ÷ 95% Class I utilization). The actual Class I price difference is only $1.89, so an argument can be made for increasing the Miami Class I price by $1.61.

Fortunately, increasing Class I prices is not the only alternative for facilitating the movement of plant milk between markets. It is possible to adopt different transfer and allocation provisions and it is possible to provide compensation for hauling costs directly out of federal order pool funds.

My conclusion is that Class I prices probably are too low. There is a need to increase total federal order revenue to attract sufficient Grade A milk to achieve blend price alignment, and there may be a need to increase Class I price differences between markets to facilitate the movement of plant milk to high utilization markets.

Do Federal Milk Orders Enhance the Market Power of Dairy Cooperatives?

One of the alleged evils of federal milk-marketing orders is their use by dairy cooperatives to exercise market power. The fact that dairy cooperatives sell milk in most markets at prices that exceed the federal order minimums is taken as conclusive evidence of market power.

I have already argued that federal order prices are inadequate to allocate properly producer milk among markets or to facilitate the movement of plant milk to high utilization markets. In spite of this inadequacy, the national milk-marketing system seems to function reasonably well. What is not generally recognized outside the dairy industry is that it is the prices charged by dairy cooperatives, and not the federal order minimum prices, that provide the incentives to make the system operate efficiently. A reasonable argument can be made that federal order prices should be modified to provide all the incentive needed, but few, if any, antagonists advance this view. Babb, Bessler, and Pheasant examined, in a recent report, over-order prices charged by dairy cooperatives. They conclude that the relationships between over-order prices and "cooperative and processor concentration were generally not statistically significant . . . [and the impact of these variables] . . . on over-order payments was small. Measures of price relationships among orders were significant and accounted for much of the variation is over-order payments" (Babb, Bessler, Pheasant, p.i). The forces that support over-order prices may in fact be economic rather than structural.

If we define market power as the ability to influence the terms of trade in market transactions, then dairy cooperatives do, indeed, exercise it. Their ability to create appropriate incentives for the production of milk and its reasonable allocation among markets indicates they are able to influence buyers to accept terms that go beyond Federal order minimums. Maybe those terms are not unreasonable in terms of competitive market forces, but they do represent more than could normally be achieved in an oligopsonistic market.

Whatever market power dairy cooperatives do possess, I think, derives mostly from the existence of federal milk orders and not much from size or concentration of sellers. The real

source of market power is the ability of the seller to deny a supply to the buyer. It is obvious that if a buyer can get an alternative supply on his own terms, the seller can exercise little market power. In unregulated milk markets, efforts to deny a supply to concentrated buyers through strikes and diversions are doomed to fail. The sellers who are individual dairy farmers, whether organized or not, suffer immediate and great economic distress and soon lose their resolve. To be successful, dairymen must find a way to maintain incomes while denying a supply to the buyer. Federal orders provide limited means for accomplishing this goal.

Liberal pooling provisions in the Chicago Regional and upper Midwest markets permit cooperatives to qualify for the blend price while diverting most or all of their milk to manufacturing outlets, instead of delivering it to a resistant fluid milk processor. The processor is faced with the choice of accepting the cooperative terms or securing an independent supply from individual dairy farmers. Securing an independent supply is an expensive alternative, because the buyer must pay prices to farmers in excess of the cooperative pay price, provide field service, coordinate trucking, control quality, payroll producers, and find facilities for disposing of reserve milk. However the opportunity for the buyer to seek an independent supply places an upper limit on the favorable terms of trade a cooperative can extract from a buyer.

The liberal pooling provisions in the Chicago and upper Midwest markets help cooperatives to charge limited over-order prices in those areas, and transportation costs permit these improved terms to be extended throughout the federal order system.

I believe federal milk orders do enhance the market power of cooperatives, but that market power is severely limited by the open opportunity for the buyer to secure an independent milk supply.

Conclusion

In evaluating the government's role in milk pricing, I see little cause for alarm. The Dairy Price Support Program provides the means for stabilizing dairy markets to the benefit of producers and consumers. The degree to which it achieves this purpose depends on administrative choices rather than on the mechanical aspects of the program. I believe an enlightened policy for the future would be to maintain intact the present program and set the support price for milk at a level that will attract a small surplus.

Issues related to the federal milk order program are more complex. While classified pricing is a necessary component in a smoothly functioning national market for fluid milk, considerable reexamination of price levels and price relationships is in order. The hearing process is appropriate and readily available to accomplish this reexamination.

Concern about the relationship of dairy cooperative market power and federal milk marketing orders is undue. Cooperatives do exercise limited market power under milk orders, but they seem to use that power to extract competitive returns, and little more.

References

Babb, E. M., and J. E. Pratt. *Projections of Federal Milk Marketing Order Performance under Alternative Pricing and Pooling Provisions.* Purdue University Agr. Exp. Sta. Bull. No. 171, Oct. 1977.

Babb, E. M., D. A. Bessler, and J. W. Pheasant. *Analysis of Over-Order Payments in Federal Milk Marketing Orders.* Purdue University Agr. Exp. Sta. Bull. No. 235, Aug. 1979.

Dobson, W. D., and Boyd M. Buxton. *Analysis of the Effects of Federal Milk Orders on the Economic Performance of U.S. Milk Markets.* Res. Pub. R2897, University of Wisconsin-Madison, Oct. 1977.

Fones, Roger W., Janet C. Hall, and Robert T. Masson. *U.S. Department of Justice Study on Milk Marketing.* Mimeographed. Washington, D.C., no date.

Gruebele, James W. "Effects of Removing the Dairy Price Support Program." *Ill. Agr. Econ.* no. 2(1978), pp. 30–38.

Masson, Alison, Robert T. Masson, and Barry C. Harris. "Cooperatives and Marketing Orders." *Agricultural Cooperatives and the Public Interest,* ed. Bruce W. Marion, pp. 187–218. N. Cent. Reg. Res. Pub. No. 256, University of Wisconsin-Madison, Sep. 1978.

Special Dairy Advisory Committee. *Examining Dairy Policy Alternatives.* Washington, D.C.: Report prepared for Milk Industry Foundation and International Association of Ice Cream Manufacturers, Sep. 1979.

U.S. Department of Agriculture, Agricultural Stabilization and Conservation Service. *Dairy Price Support and Related Programs 1949–1968.* Washington, D.C.: AER No. 165, July 1969.

U.S. Department of Agriculture, Economics, Statistics, and Cooperatives Service. *Dairy Situation.* Washington, D.C.: DS-374, DS-377, Oct. 1979.

Welfare Costs and Interregional Income Transfers Due to Regulation of Dairy Markets

Roger A. Dahlgran

The U.S. dairy industry is claimed to be unique in that it is subject to more regulation than any other agricultural industry (Hallberg and Fallert, p. 3). Whether the dairy industry is subject to more or less regulation than any other particular agricultural industry is not important. For our purposes, it is sufficient only to agree that the dairy industry is highly regulated. It is the purpose of this paper to formulate a model and estimate the interregional transfers and welfare losses created by the current regulatory structure imposed on U.S. dairy markets.

Given the degree of dairy market regulation, it would be useful to summarize the regulation that is unique to dairying. Sanitary grading was established by regulation to differentiate raw milk by its quality or condition of production. Grade A milk is produced under the strictest sanitary conditions and is eligible for fluid, or beverage, consumption. Grade B milk is produced under less strict sanitary conditions and is eligible only to be incorporated into manufactured dairy products such as cheese and butter.

Classified pricing and pooling provisions affect only grade A milk and are established by federal and/or state regulatory agencies. Classified pricing is the practice of establishing different minimum prices for raw grade A milk depending on how the milk is utilized. Grade A milk going into fluid (beverage) utilization receives the higher class I price, while grade A milk going into manufacturing utilization receives a lower class II or class III price. The class I price is typically established as the class III price plus a fixed differential.[1] Pooling is the practice of distributing the proceeds of grade A sales so that all grade A producers shipping milk into the pool receive the same or average price.

The U.S. dairy industry is also subject to a price support program which is based on the concept of parity (Hallberg and Fallert, p. 11). The price of raw milk is supported by USDA purchases of manufactured dairy products. This support of wholesale butter, cheese, and nonfat dry milk prices is transmitted back to the farm level as higher raw milk prices. In order for price supports to be effective in the United States, import restrictions have been established so the USDA can support domestic dairy prices and producers' incomes without having to support world dairy prices as well.

A final set of regulations that indirectly act upon the dairy industry consists of those that affect cooperatives. Seventy-five percent of all milk marketed in the United States is marketed through dairy farmers' coops (Jacobson, p. 171). Any regulation affecting dairy coops thus affects the structure of milk markets.

Literature Review

Ippolito and Masson formulated a national model of the U.S. dairy industry as shown in figure 1. U.S. aggregate functions are shown as *DF*, the derived demand function at the farm level for milk for fluid utilization; *SA*, the supply function for grade A milk; *AR*, the average revenue or grade A blend price function due to pooling; *DM*, the derived demand function at the farm level for milk for manufacturing utilization; *SB*, the supply function for grade B milk, assumed to be produced mainly in the Minnesota-Wisconsin area; and *DII*, the

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[1] The class II price is usually $0.10/cwt over the class III price. Henceforth, class II and class III utilization will both be subsumed under class II utilization.

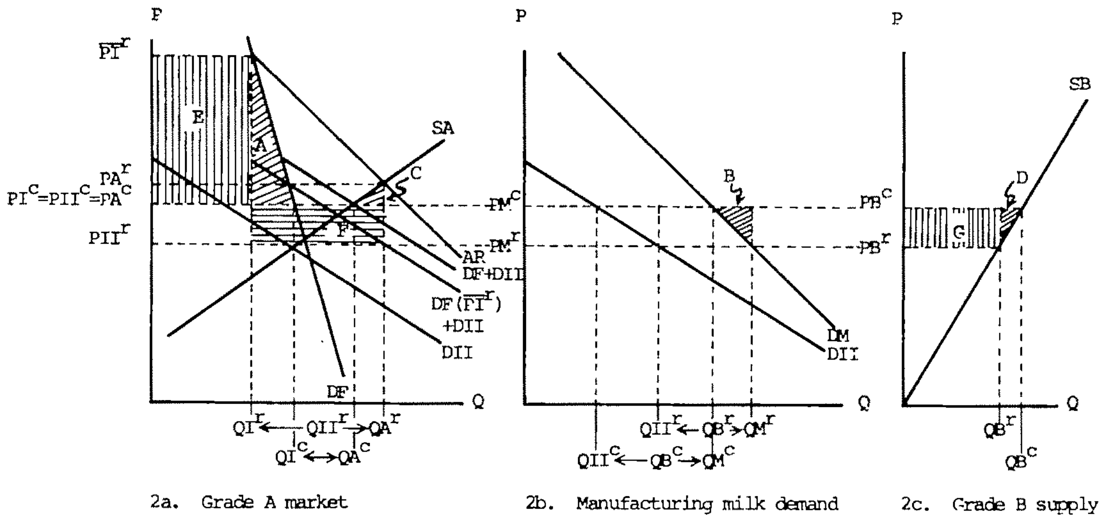

Figure 1. The Ippolito and Masson model of the U.S. dairy industry

demand for class II milk, i.e., demand for manufacturing milk net of grade B supplies. In the absence of classified pricing, the demand for grade A milk would be equal to $DF + DII$. In this case, the competitive solution would be the price-quantity vector,

$$(PI^c, PII^c, PA^c, QA^c, QI^c, QII^c, PM^c, QM^c, PB^c, QB^c).$$

With classified pricing, the minimum class I price $\overline{PI^r}$ is set administratively and results in a solution price-quantity vector,

$$(\overline{PI^r}, PII^r, PA^r, QA^r, QI^r, QII^r, PM^r, QM^r, PB^r, QB^r).$$

The welfare costs of classified pricing and pooling are shown as area A, the lost consumer surplus due to underconsumption of fluid milk; area B, the resource cost due to greater than optimal consumption of manufactured dairy products; area C, the resource cost due to overproduction of grade A milk; and area D, the resource cost due to underproduction of grade B milk. The transfers implicit in this model are area E, the transfers from fluid milk consumers to grade A milk producers; area F, a subsidy from grade A milk producers to manufactured product consumers; and area G, the transfers from grade B milk producers to manufactured product consumers. This model is a generalization of Kessel's earlier grade A model which displayed deadweight losses due to underconsumption of fluid milk, deadweight losses due to overproduction of grade A milk and transfers from fluid milk consumers to grade A milk producers.

Blakley and Riley (1974, p. 1, 1975) point out that when policy changes are under consideration, trade-offs between groups or regions may be much larger than all aggregate changes averaged over all groups. Their two studies examined the effect of alternative class I pricing policies on grade A milk markets in the United States.

The Ippolito and Masson model provides a good base for examining the magnitude of welfare costs and transfers but it does have some shortcomings. One shortcoming of the Ippolito and Masson model is, as Blakley and Riley point out, regional gains and losses may be large relative to the aggregate quantities. A second problem with the Ippolito and Masson model is the assumption of a competitive price surface. In their analysis Ippolito and Masson assumed that the Minnesota-Wisconsin area would be the only surplus producing region in the country. Subsequent analysis by Fallert and Buxton, and Hallberg et al. suggests that there would be three surplus producing regions in an unregulated environment. Another criticism of all models that indiscriminately use elasticity estimates derived from previous studies is that elasticity estimates from models that ignore the effect of regulation may be seriously biased (Prato, p. 221). A fourth criticism is not directed toward Ippolito and Masson's work but is directed toward models that assume that in competitive equilibrium the price of grade A milk will equal the price of grade B milk. This assumption is unrealistic as long as there is a cost of production differential between grade A and grade B milk produc-

tion. A final problem of measuring the welfare cost of regulation is the exclusion of risk considerations on the part of producers.[2]

Mathematical Model of a U. S. Dairy Market

On the demand side, milk is demanded at the farm level for one of two purposes; it is either bottled and sold as beverage milk or it is incorporated into manufactured dairy products. As such, there exist two demand functions for raw milk, fluid demand and manufacturing demand. Demand functions at the farm level are generally specified as[3]

$$(1)\quad QF = QF\,(PF, Inc, Pop, \mathbf{d}, t, Org, EF),$$
$$(2)\quad QM = QM\,(PM, Qs, Inc, Pop, \mathbf{d}, t, Org, EM),$$

where QF is the quantity of fluid milk demanded per day; QM is the quantity of manufacturing milk demanded per day; PF, price paid per hundredweight for milk for fluid utilization; PM, price paid per hundredweight for milk for manufacturing utilization; Inc, per capita income; Pop, population of the market; Qs, USDA price support purchases (net removals); **d**, vector of discrete monthly dummy variables to account for environmental and institutional changes over the year; t, trend variable to account for linear changes in the age distribution of the population and for linear changes in prices not included in the model; Org, discrete variable to account for market reorganizations and mergers; EF, EM, errors of estimation for the respective demand functions.

Farmers supply only two types of milk, either grade A milk or grade B milk. Mathematical optimization of the producers' profit functions subject to the industry production functions for grade A and grade B milk indicates a general formulation of the supply functions as

$$(3)\quad QA' = QA'(PA, PB, Pfd, Phy, Pcw, Pwg, Pin, \mathbf{d}, Org, EA),$$
$$(4)\quad QB' = QB'(PA, PB, Pfd, Phy, Pcw, Pwg, Pin, \mathbf{d}, Org, EB),$$

where QA' is the desired production of grade A milk per day; QB' is the desired production of grade B milk per day; PA, price per hundredweight received by farmers for grade A milk; PB, price per hundredweight received by farmers for grade B milk; Pfd, price per hundredweight paid by farmers for dairy feed; Phy, price per ton received by farmers for all hay; Pcw, price per hundredweight received by farmers for cull dairy cows; Pwg, wages paid by farmers for farm labor; Pin, interest rate on three- to five-year government bonds; EA, EB, errors of estimation for the respective supply functions.

The relationship between the actual quantity supplied and the desired quantity supplied can be specified by a linear partial adjustment model

$$(5)\quad QA_t - QA_{t-1} = a^*\,(QA'_t - QA_{t-1}) + UA,$$
$$(6)\quad QB_t - QB_{t-1} = b^*\,(QB'_t - QB_{t-1}) + UB,$$

where QA', QB' are defined above; QA, actual output of grade A milk per day; QB, actual output of grade B milk per day; a^*, b^*, respective coefficients of adjustment for grade A and grade B milk production; UA, UB, errors of estimation for the respective adjustment functions.

These supply models are interdependent in that both the grade A and grade B supply functions contain PA and PB. A great deal of multicollinearity is expected to exist between the grade A and grade B milk prices. The effect of this multicollinearity is minimized by referring to the assumption of constrained profit maximization. When this is done, a symmetry restriction emerges which specifies that either

$$(7)\quad \partial QA'/\partial PB = \partial QB'/\partial PA, \text{ or}$$
$$(8)\quad E_{QA',PB} \times PA \times QA' = E_{QB',PA} \times PB \times QB'$$

be imposed as a restriction during the estimation of the model where $E_{y,x}$ is the elasticity of y with respect to x. Normally, it is preferable to have estimates of elasticities by using double-logarithmic models. The restriction (8) associated with these supply models dictates that the estimation of price slopes is to be preferred to the estimation of elasticities since restriction (8) implies a nonlinear model.

The identities associated with this dairy market model are first, total supplies to the market are equal to total demands. Therefore,

$$(9)\qquad QA + QB = QF + QM.$$

Second, grade A farmers will receive the grade A price,

[2] If milk producers are risk-averse and regulation reduces the variance of milk prices, then the supply function will shift out as a result of regulation. More will be said about this later.

[3] These general functions may be specified as either linear or log-linear functions.

$$(10) \quad PA = [PF \times QF + PM \times (QA - QF)]/QA.$$

Third, the price paid by processors for milk for fluid utilization is the minimum class I price[4]

$$(11) \quad PF = PI.$$

And finally, all milk going into manufacturing utilization receives the same price regardless of its eligibility, so

$$(12) \quad PII = PM = PB.$$

Empirical Investigation

Since this effort is concerned with welfare costs within markets and transfers within and between markets, estimation must be performed on individual markets. At the end of 1976, fifty federal order markets and seventeen state order markets encompassed 100% of regulated milk deliveries, 97.5% of grade A milk deliveries and 79.0% of all milk deliveries. One possible approach to measuring the desired transfers and welfare losses would be to fit price and quantity data for each of these sixty-seven markets. The time required to collect and analyze the data dictated that a sampling approach be used to draw inferences about the larger population of markets. The ten largest milk markets in the United States in 1976 accounted for two-thirds of total milk deliveries and were included in the sample. Six markets from the set of fifty-seven relatively small markets were drawn at random, subject to geographic stratification. The sixteen markets included in the original sample are listed in table 1.

Several modifications were made to the original sample. The California state order market was excluded from estimation because California has a five class system of classified pricing and a complex and restrictive base plan (Milligan). The model constructed would not provide reliable elasticity estimates of supply and demand parameters in California. Second, North Carolina was included in the sample with unit probability due to the low cost of obtaining data. Finally, the Maine market was excluded due to nonresponse in data collection.

Estimation was performed using monthly time-series data from 1968–77 for the fourteen markets. All quantities were converted to per day flows to correct for different length months while all prices were deflated by the consumer price index. Not all 120 observations were used for every market as market reorganizations with few observations on the reorganized market sometimes resulted in unrealistic elasticity estimates. Table 1 lists a summary of elasticity estimates by market.

The purpose of sampling subject to geographic stratification was to measure possible regional and market size effects on elasticities of the form

$$(13) \quad E_{Q,P} = \mu + \rho_i + \sigma_j + \epsilon_{ij},$$

where $E_{Q,P}$ is a general elasticity of some quantity Q with respect to some price P, ρ_i is the effect of regional strata i, σ_j is the effect of size strata j, and ϵ_{ij} is the error of measurement. By use of least squares, $\hat{\mu}$, $\hat{\rho}_i$, and $\hat{\sigma}_j$ were estimated and these values were then used to generate a set of predicted values for $E_{Q,P}$ for all markets not in the sample. The least-squares procedure generally provided a poor description of the elasticities estimated in the sampling step as none of the t-values for $\hat{\rho}_i$ and $\hat{\sigma}_j$ were significant at the 0.10 probability level. Also, the predicted values generated by the regression model were frequently of the wrong sign. Given the insignificance of the size and regional effects, these effects were assumed to be zero and a value for each elasticity was found that is uniform across all markets. The value chosen was the mean of all the parameter estimates after severe outliers had been deleted. The resulting estimates are given at the bottom of table 1 and were assumed to apply to all markets both within and outside the sample.

Computation of the welfare costs and interregional transfers resulting from regulation requires a model of unregulated equilibrium. To model the United States dairy industry in the absence of regulation, a reactive programming model was developed using 1976 milk-marketing and utilization data. Sixty-seven fluid markets corresponding to the state and federal order markets and seventy-five manufacturing markets were identified in terms of prices, quantities, and geographical coordinates. Supply areas were assigned geographically as states and likewise were identified by prices,

[4] The actual price paid for fluid milk is frequently the federal order minimum plus an over-order premium. This over-order premium reflects the cost of services performed by cooperatives, the cost of obtaining alternative supplies, and any supracompetitive premium. The assumption of the constancy and independence of this over-order premium and the error of the fluid equation was utilized. The class I minimum price was then a proxy for PF.

Table 1. Summarization of Estimated Policy Elasticities

		Demand Elasticities					Supply Elasticities			
		Fluid		Manufacturing			Grade A		Grade B	
Market[a]	% US Total Del.	*PF*	Std. Err.	*PM*	Std. Err.	*Qs*	*PA*	*PB*	*PA*	*PB*
California (state)	11.5	—	—	—	—	—	—	—	—	—
Chicago regional	10.7	−0.0792	0.0416	−0.123	0.120	0.00873	4.87	−4.01	−1.86	1.87
New York, New Jersey	10.4	−0.0590	0.0725	−0.364	0.142	0.00155	−0.0269	0.000	—	—
Middle Atlantic	5.9	−0.168	0.0913	−0.646	0.208	0.000149	0.770	−0.0532	−0.597	0.657
Upper Midwest	5.9	−0.194	0.109	−0.0933	0.0999	0.0211	4.74	0.000	0.000	−2.50
New England	5.5	−0.109	0.0574	−0.286	0.398	−0.0134	2.48	0.000	—	—
Southern Michigan	4.4	−0.0919	0.0416	−0.682	0.167	0.00859	0.339	0.000	0.000	−0.654
Eastern Ohio, western Penn.	3.8	−0.184	0.0447	−0.252	0.214	0.00818	0.517	−0.0636	−0.656	1.02
Texas	3.8	−0.166	0.119	0.942	0.479	0.00165	3.61	0.000	—	—
Ohio Valley	3.3	−0.183	0.0906	−0.485	0.174	0.0130	0.770	−0.223	−0.776	0.778
North Carolina (state)	1.6	−0.508	0.0448	0.674	0.346	0.00538	−0.000	0.000	—	—
Oklahoma metropolitan	0.9	−0.160	0.437	−0.561	0.560	−0.00945	2.02	−0.642	−1.63	1.05
Nashville	0.7	0.0195	0.140	0.136	0.258	0.00828	1.00	0.000	0.000	0.639
Quad cities, Dubuque	0.4	0.509	0.529	−0.130	0.124	0.00769	1.23	−0.723	−1.35	0.269
Maine (state)	0.3	—	—	—	—	—	—	—	—	—
Nevada (state)	0.1	−0.189	0.354	−0.248	0.469	0.0173	0.237	0.000	—	—
Average value		−0.112	—	−0.352[b]	—	—	1.74[c]	−0.953[b]	−1.14[b]	0.897[c]

[a] All markets are federal order markets unless otherwise specified.
[b] Only negative estimates are included in the calculation of the mean.
[c] Only positive estimates are included in the calculation of the mean.

quantities, and geographical coordinates. Both the supply and the demand areas were then aggregated into regions. Distances between supply and demand regions were computed (see Tramel and Seale) and converted to transportation costs using the formula given by Lough (p. 18). Manufacturing milk transportation costs were computed as the cost of shipping the fluid milk equivalent in manufactured products and were computed to hold the same proportional relationship to fluid transportation costs as in Hallberg et al. Fluid and manufacturing demand regions were assumed to have an elasticity of demand equal to -0.112 and -0.352, respectively. Since grade A and grade B production are interdependent, it was assumed that in an unregulated environment the fall in the grade A price and the rise in the grade B price would cause grade A producers to convert to grade B production until the cost of production differential was attained and total manufacturing demand was supplied out of grade B production. In terms of the modeling effort, this assumption was incorporated by using a total supply function and the assumption that, in unregulated equilibrium, the grade B price would be below the grade A price by the cost of production differential, $0.15 per hundredweight [Ippolito and Masson (citing Bartlett), p. 37]. The elasticity of the total supply function was specified with respect to the grade A price since there is a one-to-one correspondence between the grade A price and the grade B price in unregulated equilibrium. Specifically, since

$$(14) \qquad QT = QA + QB, \text{ then}$$

$$(15) \qquad E_{QT,\,PA} = \frac{QA}{QT} E_{QA,\,PA} + \frac{QB}{QT} E_{QB,\,PA} = 1.19,$$

which was the assumed elasticity of total milk supplies with respect to the grade A price.[5]

In order to have grade B prices the required $0.15 per hundredweight below grade A prices in the final solution, manufacturing demand was inflated by 1.5% to give manufacturing demand in terms of the grade A price. When the solution was obtained, the manufacturing demand function, which was formulated in terms of the grade A price, corresponded to the true manufacturing demand function, which was formulated in terms of the grade B price. The difference between these manufacturing demand functions was the required $0.15 per hundredweight. The reactive program was initialized at the 1976 actual prices and quantities and converged to equilibrium according to the assumptions outlined above.

Results

While total milk quantities, expenditures, and receipts will change relatively little with the presence or absence of regulation, the allocation of production between grade A and grade B producers will vary dramatically (table 2).

[5] This value was computed using 1976 quantity data (table 2) and estimated elasticity values (table 1).

Table 2. Comparison of 1976 Actual Regulated Dairy Economy with 1976 Simulated Unregulated Dairy Economy in Terms of Prices, Commodity Flows, and Values

	Actual Regulated			Simulated Unregulated		
Utilization	Grade A	Grade B	Total	Grade A	Grade B	Total
Fluid						
Price ($/cwt)	10.80	—	10.80	9.95	—	9.95
Quantity (bill lbs)	51.5	—	51.5	52.0	—	52.0
Value ($ bill)	5.56	—	5.56	5.17	—	5.17
Manufacturing						
Price ($/cwt)	8.63	8.55	8.63	9.49	9.49	9.49
Quantity (bill lbs)	42.0	21.9	64.0	0.0	61.1	61.1
Value ($ bill)	3.62	1.87	5.52[a]	0.00	5.80	5.80
Total						
Price ($/cwt)	9.91	8.55	9.59	9.72	9.46	9.64
Quantity (bill lbs)	93.5	21.9	115.5	52.0	61.1	113.1
Value ($ bill)	9.27	1.87	11.08[a]	5.05[b]	5.78[b]	10.83[b]

[a] Value does not sum horizontally due to use of different data sources.
[b] Value does not sum vertically due to transportation costs which are subtracted out in the reactive programming solution.

The effect of regulation in terms of tax rates on fluid milk consumption and grade B milk production and in terms of subsidy rates on the production of manufactured goods is recorded in table 3. The effect of regulation is not as clear-cut on grade A prices. Generally, regulation imposes a tax on grade A production in the upper Midwest, northern Great Plains, and California regions while subsidizing grade A production in all other regions. Changes in economic surpluses also are recorded in table 3. These surplus changes are as predicted by the model and are a function of the implied tax rates. These surplus changes are also quite large and are composed of the indicated transfers and deadweight losses. The deadweight losses due to the misallocation of consumption (columns A and B) are generally small because of the inelasticity of demand.

Given the construction of the supply response for the model, dead-weight losses in production were redefined from the areas *C* and *D* shown in figure 1. The social costs due to resource misallocation between milk and all other production are recorded in column C and the social costs due to resource misallocation within milk production are recorded in column D, both in table 3.

The total deadweight losses were estimated as $96.8 million, the bulk of which comes from the production of grade A surpluses in a regulated environment. By comparison, Kwoka estimated $179 million to be the welfare losses of dairy market regulation and $750 million to be transferred from fluid milk consumers to grade A milk producers (corresponding to column E) for 1970. For 1973, Ippolito and Masson estimated total deadweight losses to be roughly $26 million per year, administrative costs to be roughly $34 million per year, and transfers corresponding to columns E, F, and G to be $334 million, $121 million and $105 million, respectively. As was pointed out by Ippolito and Masson, in addition to the deadweight losses due to regulation, the costs of administering the system must be added to determine the total social costs due to regulation.[6] Using the Ippolito and Masson administrative cost estimates of $34 million, the total social cost of dairy market regulation can be found to be $131 million for 1976. This $131 million includes the cost of both the price support program which purchased 1.9% of total manufacturing utilization in 1976 and the classified pricing and pooling program. If price support purchases had been greater, driving dairy markets farther away from the assumed unregulated equilibrium, the computed deadweight losses would have been larger.

Stability is one alleged benefit of dairy market regulation in that one result of regulation is the creation of grade A surpluses which insulate retail milk prices from the effect of annual supply and demand cycles. The model formulated to estimate transfers and deadweight losses does not provide a cushion for the short side of the grade A supply relative to the fluid demand cycle. However, the estimated supply and demand functions for the fourteen sample markets allowed the estimation of the mismatch between the grade A supply cycle and the fluid demand cycle. At constant prices, the maximum grade A shortfall of 9.0% occurred in the month of October, while the maximum grade A surplus of 13.0% occurred in the month of June. A 9.0% annual grade A surplus, which is sufficient to cover the short months was calculated to cost $7.0 million ($0.15/cwt × 9.0% × grade A supply).

Another frequently argued benefit of regulation is that regulation reduces the price risk for producers and the supply function shifts outward as a result of regulation. While the existence of this phenomenon is open to investigation, there are two implicit assumptions; first, that dairy farmers are risk-averse and second, regulation does indeed reduce the price variance. The testing of these assumptions will be left to a later time.

The supply structure in unregulated equilibrium was assumed to be the same as the observed supply structure in regulated equilibrium. The question asked of the model was how far must this supply structure have shifted out because of regulation in order for consumer surplus gains to offset the deadweight losses. It was found that if the regulated supply function had shifted out by 1.54% or more, then the deadweight losses would have been more than offset by the consumer surplus gains. The issue again becomes clouded by the possibility that regulation merely shifts risk from grade A to grade B producers. Given the level of belief in the stabilizing effect of dairy market regulation, the study of the existence of this effect and its relationship to producers' output decisions deserves more attention in the years to come.

[6] Some of these administrative costs go toward providing market information which is a benefit and will to some extent offset these administrative costs.

Table 3. Tax and Subsidy Rates, Surplus Changes, Deadweight Losses and Transfers Due to Regulation of U. S. Dairy Markets

	Tax (−) & Subsidy (+) Rates[a]				Surplus Changes[b]				Areas in Figure 1[b]						
	Production		Consumption		Production		Consumption		Deadweight Losses				Transfers		
Region	GrA	GrB	Fld	Mfg	GrA	GrB	Fld	Mfg	A	B	C	D	E	F	G
Northeast	3.7	−13.8	−13.4	14.0	41.7	−28.4	−122.3	98.1	0.86	2.60	2.14	6.48	121.4	67.3	0.0
Mid Atlantic	7.7	−11.1	−14.7	9.0	63.9	−24.9	−88.9	37.2	0.68	0.61	7.22	5.47	88.2	40.2	5.7
Southeast	5.5	−20.9	−4.6	9.7	29.0	−1.3	−26.4	13.5	0.07	0.24	1.86	−0.18	26.4	−2.6	2.5
Upper Midwest	−2.1	−8.6	−1.7	7.2	−28.5	−158.4	−11.9	162.6	0.01	4.87	1.68	22.95	11.9	99.3	96.0
Corn Belt	2.5	−11.0	−6.5	7.9	24.3	−77.7	−42.9	64.7	0.15	0.93	1.23	9.12	42.8	49.5	46.0
South Central	8.7	−15.4	−12.7	10.6	31.9	−16.2	−30.9	17.2	0.21	0.34	4.06	1.64	30.7	21.3	8.2
N. Plains	−3.7	−11.0	−1.5	9.8	−1.8	−20.7	−0.4	11.6	0.00	0.21	0.41	0.90	0.4	4.5	17.5
C. Plains	3.1	−11.1	−7.2	9.2	6.8	−12.0	−13.8	31.4	0.05	0.53	0.38	0.78	13.7	5.8	9.3
S. Plains	7.9	−12.0	−11.4	9.8	29.1	−3.5	−37.3	14.7	0.23	0.27	2.85	0.71	37.1	8.3	0.7
N. Mountain	−0.1	−6.6	−1.0	7.5	−0.1	−7.6	−0.2	5.9	0.00	0.08	0.00	1.07	0.2	5.0	5.4
C. Mountain	0.5	−5.1	−7.7	7.6	0.4	−1.4	−4.7	5.7	0.02	0.08	0.00	0.31	4.7	1.6	0.9
S. Mountain	7.2	−8.8	−14.1	8.8	7.1	−1.1	−11.6	3.5	0.09	0.06	0.67	0.40	11.5	3.1	0.0
Pacific NW	1.7	−0.9	−8.9	5.4	3.7	−0.7	−13.6	9.4	0.06	0.09	0.10	2.13	13.5	7.6	0.1
California	−1.9	−13.0	−6.4	13.1	−14.9	−36.7	−36.7	60.7	0.13	1.49	0.47	7.06	36.6	55.0	8.0
Total or avg	2.0	−9.7	−8.6	9.0	192.5	−390.6	−441.7	536.3	2.56	12.40	23.06	58.85	439.1	365.9	200.4

[a] Expressed as a percentage.
[b] Million dollars.

References

Blakley, Leo V., and John B. Riley. "Impact of Alternative Class I Pricing Systems on Fluid Milk Prices." *Amer. J. Agr. Econ.* 57(1975):67–73.

———. "Regional Gains and Losses for Consumers and Producers from Changes in Fluid Milk Prices." *S. J. Agr. Econ.* 2(1974):1–8.

Fallert, Richard F., and Boyd M. Buxton. *Alternative Pricing Policies for Class I Milk under Federal Marketing Orders—Their Economic Impact.* Washington, D.C.: USDA ESCS Agr. Econ. Rep. 401, May 1978.

Hallberg, Milton C., and Richard F. Fallert. *Policy Simulation Model for the United States Dairy Industry.* Pennsylvania State University Agr. Exp. Sta. Bull. No. 805, Jan. 1976.

Hallberg, M. C., D. E. Hahn, R. W. Stammer, G. J. Elterich, and C. E. Fife. *Impact of Alternative Federal Milk Order Pricing Policies on the U.S. Dairy Industry.* Pennsylvania State University Agr. Exp. Sta. Bull. No. 818, May 1978.

Ippolito, Richard A., and Robert T. Masson. "The Social Cost of Government Regulation of Milk." *J. Law and Econ.* 21(1978):33–65.

Jacobson, Robert E. "Sources, Limits, and Extent of Cooperative Market Power: Cooperatives and Marketing Orders." *Agricultural Cooperatives and the Public Interest*, pp. 171–86. North Central Reg. Res. Pub. 256, University of Wisconsin, Sep. 1978.

Kessel, R. A. "Economic Effects of Federal Regulation of Milk Markets." *J. Law and Econ.* 10(1967):51–78.

Kwoka, John E., Jr. "Pricing under Federal Milk Market Regulation." *Econ. Inquiry* 15(1977):367–84.

Lough, Harold W. *Truck Transportation Costs of Bulk Milk.* Washington, D.C.: USDA ERS CED, Aug. 1977.

Milligan, Robert A. *An Economic Analysis of the Factors Affecting the California Dairy Industry.* Calif. Agr. Exp. Sta.–Giannini Foundation Res. Rep. No. 325, Feb. 1978.

Prato, Anthony A. "Milk Demand, Supply, and Price Relationships 1950–1968." *Amer. J. Agr. Econ.* 55(1973):217–22.

Tramel, Thomas E., and A. D. Seale, Jr. "Estimation of Transfer Functions." *Interregional Competition Research Methods*, ed. Richard A. King, pp. 175–7. Raleigh, N.C.: Agricultural Policy Institute Series 10, 1963.

Milk Prices and the Public Interest: Discussion

Leo V. Blakley

A variety of conclusions and opinions on welfare costs associated with federal order regulation of milk markets has been presented in papers that can be classified as adversary, econometric, and evaluation papers. The classified pricing system, premiums over federal-order minimum prices, and allegations of nonvalues for expenditures associated with federal orders are the bases used for measuring social costs and income transfers.

The classified pricing system, by definition, results in income transfers from consumers of fluid milk and producers of manufacturing grade milk to consumers of manufactured milk products and producers of Grade A milk. The transfers are large, as shown by Dahlgran. One purpose of the classified pricing system is to increase producer prices, and modest increases have been obtained. Based on Dahlgran's 1976 equilibrium values of milk in all regions, the increase was \$0.07 per hundredweight, but with 2.3 billion pounds more milk produced in 1976 than in the simulated results.

Classified pricing under the orders does not maximize producer income but this failure to maximize income does not imply that there is "room for monopoly power." Control of quantity supplied would be necessary even to approach allocations which result in marginal revenues of zero (or above) in the three markets. There are no mechanisms under milk orders to achieve supply controls or even to prohibit milk producers in any geographic location from selling milk under an order in another region. Without controls on the production of milk there can be no monopoly.

Premiums over federal order minimum Class I prices constitute the basis for many of the social costs calculated by Masson and Eisenstat. Such premiums result from many factors as discussed by Christ and include costs of providing services to handlers, temporary shortages in supply, temporary surges in demand, and limited market power within spatially separated markets. Babb's model is superior to the Masson-Eisenstat models for estimating either the reasons for premiums over federal order minimum prices or the impact of market share on premiums. Babb, Bessler, and Pheasant (p. 57) found that if a 20¢ per hundredweight handling charge were the actual cost, and if it could be charged in all markets, the elimination of all other premiums would result in only a 3¢ reduction in U.S. blend prices. The portion of this 3¢ which was due to costs of solving temporary supply-demand problems in individual markets and the portion which was due to market power is subject to debate, but the latter is certainly less than the 3¢ per hundredweight.

Cross-market pooling (or the emotionally charged term of pool loading) was defined in such a way that a cooperative would automatically qualify for the charge of pool loading if it attempted to move milk to meet all Class I needs, minimize east-west movements (which have no price credits to offset transportation costs) and to minimize total transportation costs. There is no line around a market which can be drawn to say that a producer in a given location should always have his milk delivered to that market. If milk supplies are coordinated, it will not necessarily be picked up on the same farm assembly route on Sunday as on Friday. Neither can it be assumed rationally that the cost of servicing a market is constant with respect to market share or that a cooperative can always obtain the premium necessary to cover the cost of servicing the market. While widely separated markets offer the potential for small premiums based on the cost of shifting supplies from one market center to another, substantial premiums do not persist in the longer run since producers can change markets and both producers and processors can and do make new marketing arrangements.

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The "standby pool," contrary to the allegations, had its origin in discussion and planning long before implementation in 1967. The standby pool was initiated because there was nothing equivalent to Order 68, not vice versa. It was set up as a contractual reserve supply at an "insurance" cost equivalent for cooperatives to move fairly large quantities of milk if needed for contractual obligations. On individual days as much as two-thirds of the milk under contract was called for delivery. None was called in the flush period. The total milk under contract was small relative to either the uncommitted supply of Grade A milk or the annual rate of conversion from B to A.

How large are the social costs and how large compared with what? If $70 million were accepted at face value, the costs would represent 0.6% of the farm value of all milk reported by Dahlgran. Mueller (p. 6) regards this as a very modest figure in light of Scherer's estimates of 1.7% of gross national product for deadweight loss and transportation inefficiencies associated with the exercise of market power in the economy and a total market power cost of 6.2%. It also is modest compared with Greig's (p. 29) estimate of 3.6% to 5.0% of gross national product for social costs of imperfections in atomistic food markets. Greig's costs under competition include lack of economies of scale and firm size, excess capacity, and cross-hauls of plant mislocations.

Implicit in the calculation of social cost is measurement from the "purely competitive norm." I have no quarrel with the use of the competitive norm as an analytical tool, and it can be the basis for judging imperfections in our economic system. It cannot, however, be the basis for judging the consequences of altering economic and institutional arrangements on one side of the market.

The inference that elimination of federal orders and antitrust immunities for cooperatives will improve social welfare by the amounts reported is wrong for at least five reasons. First, the buyer side of the market is oligopsonistic; not purely competitive. Under a market order, the marginal resource cost and the supply price is approximately the same for all firms, and removal of federal orders would result in an income transfer from producers to the processing firms equivalent to the monopsony profit that could then be obtained.

Second, the measurements assume either given quantities of milk produced or the continued validity of supply schedules generated under federal orders and cooperatives. Dahlgran's analysis of uncertainty is not adequate, as he recognized. Moving back to marketing conditions in which producers do not know the price or whether a fluid milk market can be found each day would drive producers out. It is not as simple as a telephone call. In addition, the uncertainty would change the organization of resources at the firm level to be able to cope with variable prices and outputs. A major impact of this uncertainty would be on the structure of dairy farms. Up to 1974, dairy farming had less concentration of farm production than fifteen other farm enterprises (Jacobson, p. 20). About 83% had herds smaller than fifty cows. If small dairy farm numbers would decrease as much as cotton farms numbers declined when price uncertainty was substituted for price certainty, then small dairy farms would decrease by about 50% in five years. This would shift the supply schedule to the left and result in substantial increased social costs.

Third, as emphasized by Christ, consumers have benefited from price stability provided in part through reserve supplies accumulated under the support program. The curvature of the consumer demand schedule appears to be such that consumers lose when price instability of the type experienced for beef or grain in the 1970s is substituted for price stability.

Fourth, market order administrators perform services to both producers and processors which have value and would be required in the absence of federal orders. Minimum physical losses in plants, safeguards to ensure accurate producer milk weights, tests and quality, and assurances of proper accounting for use of producer milk represent some of the legitimate concerns which would entail costs to processors and producers.

Fifth, cooperatives perform most of the services involved in coordinating milk supplies to meet processing needs. Each firm can have deliveries of the quantities and qualities of milk at given plants and given times according to its own schedule of needs. The firm can choose the number of processing days per week and has the option of developing supplies of its own with purchases of supplemental milk needed to meet daily or seasonal variations in the demand for its products. The handling of reserve supplies associated with performance of the coordination function is costly, particularly in the high utilization markets of the southwest and southeast.

Stellmacher (p. 98) estimated the savings from centralized coordination in the southern region of AMPI have been 5.5 to 7.4 million dollars per year since 1968, just for the processing of 0.7 billion pounds of reserve supplies into manufactured products. These savings resulted from closing small inefficient plants and from minimizing the transportation costs of moving milk from farms to processing plants. The savings from elimination of duplicate farm assembly routes and from coordination of Grade A supplies now being analyzed would add to these savings. Substantial savings for comparable actions have occurred in the other regions for the 7 billion pounds of reserve Grade A and manufacturing grade milk processed into manufactured products.

An error, repeated often enough, sometimes gains acceptance by repetition and quotation. Such is the case with statements implying that classified pricing was initiated in response to farm conditions during and after the depression. Classified pricing in fact was initiated before 1920 because the alternative, flat pricing, led to problems of inadequate supplies during parts of the year and to problems with producers concerning the price level. The codification of this institutional arrangement after the depression was a codification of an arrangement which had been developed and was in operation in previous time periods. The basic institution of mandatory support prices for dairy products, on the other hand, was a product not of the depression but rather of an attempt to increase milk production during World War II.

Equating AMPI with Standard Oil or U.S. Steel is ridiculous. There are checks and balances on the management of a milk-marketing cooperative which do not exist for the management of a corporation such as U.S. Steel. The aim of the cooperative is to enhance producer income within the rules of the game in bargaining, merchandising, generic advertising, and product research. Producers have final control over management through member votes and boards of directors composed of members. The majority of members can change the board, the management, or the existence of the cooperative itself by their actions. I would not assert that every action or bragging statement by any person in the cooperative was always right, but I would assert that actions were undertaken with the objective of improving income of dairy farmers and that illegal actions by management would not knowingly be tolerated in the long run by most of the producers and board members I know. In addition, the marketing function is carried out under federal orders, and the administrators of these federal order programs should be commended—not condemned. In a fast-changing economic environment, changes in the rules have come quickly when questionable interpretations or possible abuses were involved. Innovations such as supply-demand adjusters which appeared good in theory have been implemented then abandoned when the desired results were not achieved. Finally changes in the rules for pricing properly have come slowly and after much deliberation.

In conclusion, I wish to thank the authors for presenting a variety of viewpoints concerning federal regulation of milk markets. The magnitude of social costs should always be under surveillance. It would be incorrect to infer that elimination of the federal orders with its public hearing process would result in increased consumer welfare. Most likely, the effect would be decreased consumer welfare as production decreased. Finally, I have refrained from entering into a discourse on the many allegations with which I disagree.

References

Babb, E. M., D. A. Bessler, and J. W. Pheasant. *Analysis of Over-Order Payments in Federal Milk Marketing Orders*. Purdue University Agr. Exp. Sta. Bull. 235, Aug. 1979.

Greig, W. Smith. *The Changing Structure of the Food Processing Industry: Description, Causes, Impacts and Policy Alternatives*. College of Agr. Res. Center Bull. 827, Washington State University, Sept. 1976.

Jacobson, Robert E. *Changing Structure of Dairy Farming in the United States: 1940–1979*. Dep. Agr. Econ., Ohio State University, 1979.

Mueller, Willard F. *Federal Milk Marketing Orders*. NC project 117, Work. Pap. Ser. WP-28, University of Wisconsin, Feb. 1979.

Stellmacher, Michael J. "Mergers and Efficiency in Cooperative Milk Assembly and Manufacturing in the Southwest." M.S. thesis, Oklahoma State University, 1979.

Milk Prices and the Public Interest: Discussion

Alden C. Manchester

This session and each of the papers owes its existence to the regulatory reform hypothesis and the flowering of debate stemming from it. This hypothesis holds that the regulation or legislation in question was initiated many years ago in one depression or another to meet conditions which were peculiar to those depression years. The depression is gone but the regulations are still with us. It goes almost without saying that regulations appropriate to depression conditions are quite inappropriate in the affluent eighties. Implicit in the argument is the conclusion that, because the legislation has not changed in major degree, the regulation likewise has not changed.

The "proofs" of the verity of this hypothesis are based on bad history, which almost completely ignores the transformation of milk-marketing orders from a system of local markets in the thirties to a national system of interrelated regional markets in the seventies.

A great many things indeed have changed since 1937, but some fundamentals have not. Milk is still produced every day and moved to market at least every other day. Despite the best management, cows do not produce on the schedule demanded by the buyers. This requires more management in balancing milk supplies than was needed during the depression. There are substantial economies of scale in balancing milk supplies, and cooperatives can achieve them. Despite economies of scale, there are still substantial costs in performing the balancing function. The firm which can avoid these costs by allowing someone else to perform the function receives substantial benefits. This applies to producers, cooperatives, and processors. Thus, many of the major reasons for the federal order program still exist.

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The Antitrust Exemption

Section 1 of the Capper-Volstead Act provides that agricultural marketing cooperatives are partially exempt from the antitrust laws. Masson and Eisenstat—following the National Commission for the Review of Antitrust Laws and Procedures which followed the Antitrust Division's lead—recommend the dismantling of the Capper-Volstead Act. The only exemption preserved would provide that the act of farmers joining together to form a marketing cooperative would not be considered a conspiracy and therefore illegal. Marketing agencies in common and federations would be outlawed. Mergers between cooperatives would be subject to the same rules as those of other corporations, which would effectively prohibit mergers by cooperatives of significant size.

This is the extreme case of the application of the "small is beautiful" doctrine. In this view, the status of agriculture as the last redoubt of something resembling textbook-perfect competition is to be preserved at all costs. If the peasant farmer is too poor to support his family with dignity, some form of a welfare program is to be provided, but at all costs society is to avoid giving any market power. Cooperatives are acceptable as long as they resemble the handful of Rochdale weavers who started the cooperative way of life in 1844.

The Political Economy of Classified Pricing

The existence of classified pricing is an affront to economists, lawyers, and consumer advocates because, as everyone knows, classified pricing is equated with price discrimination. And price discrimination is illegal under the Robinson-Patman Act, although explicitly permitted under the Agricultural Marketing Agreement Act. So the lawyers know that is just another special favor for agriculture. Economists can look at the price discrimina-

tion diagram and conclude that consumer surplus is smaller and producer surplus larger with price discrimination than without it.

But all that glitters is not price discrimination. Economic price discrimination is defined as charging different net prices to different buyers for the same product. Nominal prices are easy to compare. Net prices are much more difficult, since they require substantial amounts of cost information as well as quoted prices. Comparison of prices for the same product requires that the product be identical in space, time, and form utility or that differences in these utilities be costed out into net prices.

It is argued by Masson that any difference in the price for milk from, say, a given tankload which is used for different purposes is conclusive evidence of price discrimination and of excessive market power on the part of the seller.

In any given tankload of milk, the objective characteristics of the parts of the lot used for fluid milk or for ice cream or butter-powder are certainly identical. But the value in economic terms of the milk used for ice cream is significantly less than that used for packaged milk. The economic principles embodied in location theory tell us that in a perfect market the value of milk for fluid use at a city plant is given by cost of transportation of bulk milk from the outer reaches of the milkshed, but the value of milk for use in ice cream is limited by the cost of transporting ice cream or ice cream mix from plants in the surplus production area. The economic forces represented by these principles are at work with or without the intervention of public regulation.

Thus, milk for use in ice cream can only move to a city plant at a price which does not exceed the cost of the other ingredients—e.g., ice cream mix—from somewhere else, providing there are no restrictions on movement or requirements that only local milk can be used to manufacture ice cream.

But, in this free-flow market, there will be no milk for use in fluid products if the higher price including transportation is not paid, because it obviously pays the producer better to sell to manufacturing plants in the outer reaches of the milkshed.

In terms of demand curves, the demand for raw milk for use in ice cream is zero if priced the same as that used in fluid products, because the entire demand already has been met by ice cream mix from more distant areas.

In such a situation, in a perfectly planned world, precisely as much milk would be produced in the local milkshed as was needed for fluid milk products and all ice cream would be made from shipped-in mix. But since cows produce varying amounts, storms interrupt assembly and hauling, and consumers do not behave according to plans, some mismatch between production on the farms and plant use for packaging is inevitable. It is obviously less wasteful to use the surplus milk (the reserve against running out) for manufactured products than to put them down the drain—which is now illegal in most jurisdictions because it creates additional load at the sewage plant.

Thus, that which is so crystal clear when one looks at a single, isolated tankload of milk takes on very different dimensions when one looks instead at the flow of milk day after day. Because it is the flow of milk which must be priced rather than a single lot, the dimensions of space, time, and form utility are changed. The "market" for that isolated tankload of milk at the dock of the city milk plant is only an incident in an interconnected set of markets for milk in all its forms and for all of its products.

Classified pricing of milk was invented to deal with these problems which are basically unchanged in 100 years. The additional possibility of price discrimination was discovered much later. It had to await the development of market power.

According to the calculations of Masson and colleagues, the social costs of federal and state regulation were $30 million in 1973, and those of "cooperative monopoly power," $41 million. This equals 0.8% of consumer expenditures for fluid milk and cream or about 1.1¢ per gallon. We are told that up through early 1978 over half of the "cooperative monopoly" social costs have been eroded by the beneficial effects of the consent decrees. Rising transportation costs since 1973 which were not offset by increased transportation allowances under federal orders probably would more than wipe out the calculated social costs of federal and state regulation.

The magnitude of these social costs fails to strike terror in my heart—1973 social costs of 1.1¢ a gallon simply fail to impress. Discussion of such magnitudes is reminiscent of the heated arguments of medieval theologists over how many angels could dance on the head of a pin.

But persist we must, for even these insig-

nificant amounts ignore reality. Ignored is the comprehensive analysis of Babb and associates (Babb, Bessler, Pheasant) who find no significant effect of cooperative market power, whether measured by the market share of one or four cooperatives, on the size of over-order payments.

Even more serious to a consideration of the validity of these or anyone else's estimates is their ignoring the costs, other than transportation, of marketing bulk milk for use in fluid milk products. These costs exist and must be covered by the marketing system in one way or another. They are not the result of monopoly power. On the contrary, they would be much higher if large cooperatives were broken up and the system no longer had the benefit of economies of scale. An exemplary study by Christensen and associates (Christensen, Petterson, Swainston) found these costs to be about 50¢ per hundredweight in 1977, which would be nearer 60¢ today.

Thus, I conclude that the social costs of federal and state milk regulation and of cooperative market power as measured by Masson and company are either insignificant or nonexistent. The omissions I see would all have the effect of lowering their estimates. Unless someone else perceives major omissions or errors which would raise the estimate, I see no reason to try to do it better.

On the other hand, the benefits so cavalierly dismissed by Masson and Eisenstat are far from trival. For better or worse, economics lacks the conceptual basis and measurement tools to deal with dynamic problems, so we cannot measure the benefits of stability. Clearly, the combination of the federal price support and milk order programs and of cooperative activities have provided a major element of stability in dairy production markedly different from that in other parts of animal agriculture. It seems to me highly significant that milk production is far-and-away the least concentrated in animal agriculture except for hogs, where the limits are set by disease problems. Dairy farming is still family farming, which can hardly be said for integrated production of eggs, broilers, or turkeys, or for large-scale cattle feedlots. No other sector of animal agriculture has federal programs, nor are cooperatives of major importance. The prudent policy maker concerned with the public interest might be well-advised to consider this phenomenon carefully before he decided to abolish the programs in question.

References

Babb, E. M., D. A. Bessler, and J. W. Pheasant. *Analysis of Over-Order Payments in Federal Milk Marketing Orders*. Purdue University Agr. Exp. Sta. Bull. No. 235, Aug. 1979.

Christensen, Rondo A., Doyle E. Petterson, and Allan H. Swainston. *The Function and Cost of Balancing Market Milk Supply with Demand*. Econ. Res. Inst. Stud. Pap. 79-5, Utah State University, Aug. 1979.

Post-Keynesian Economics and Agriculture
(Edna T. Loehman, Stanford Research Institute, Chairperson)

Agriculture and the Rest of the Economy: Macroconnections and Policy Restraints

Graciela Chichilnisky and Lance Taylor

The economic relationships between the agricultural and nonagricultural sectors have long been scrutinized, with a number of key linkages singled out—investment requirements and the macroadjustments between the two sectors that permit savings to come forth; nonagricultural demand for employment and food confronting agricultural supply response; shifts in income distribution that ensue as people move from agricultural/rural to nonagricultural/urban occupations and economic roles. In this paper, we develop diagrammatic models to illustrate short- and long-run aspects of these two-sector interactions and their implications for policy. Both models are "post-Keynesian" in their focus on Keynes-like savings-investment approaches to the macrosystem, and Ricardo-like determination of the functional income distribution via the real wage. But they also follow tradition in addressing questions under debate for decades and likely to be controversial for time to come. In that sense, we add only novel presentation and a few modern twists to strands of macrotheory that Arthur Lewis, Simon Kuznets, Richard Eckaus, Latin American structuralists, and the participants in the Soviet industrialization debate started to spin long ago.

The first two sections of the paper are devoted to a combination of the Kuznets and structuralist stories, where we ask how the agricultural/nonagricultural terms of trade and income distribution must adjust to permit both savings-investment and commodity market balance to be assured. It will be shown that inflationary processes can easily be kicked off by terms of trade movements in the short run. In the next two sections we follow Chichilnisky in working out a longer run, Lewis-style model in which economic dualism plus an elastic labor supply can lead to severe problems with realization of the marketed surplus and agricultural exports abroad. A brief final section summarizes the major implications of the models for policy choice.

Investment Demand, Savings Supply, and the Terms of Trade

The agricultural terms of trade are supposed to balance many forces—food demand, producer supply, and agricultural savings in response to investment needs. Which factors dominate movements in the terms of trade and which are relatively unimportant may vary with the conjuncture, and more generally with the institutions of the economy at hand. In this section, we present a four-quadrant diagram which helps isolate controlling forces and we identify the conditions under which each may reign.

The general equilibrium of the terms of trade appears in figure 1. The equilibrating variables are the price of agricultural (or A-sector) output, and output itself in nonagriculture (N-sector). The diagram shows how these variables are determined jointly in the market for nonagricultural goods in the upper quadrants and by aggregate demand and supply (or savings and investment) below. When both savings-investment and N-sector commodity balance are in equilibrium, then so will be the market for agriculture by Walras's Law.

To explain the diagram we discuss the relationships depicted in each quadrant, beginning with the northwest. The agricultural price is measured on the horizontal axis running left from the origin, and demand for nonagricultural products on the vertical axis pointing up. Demand faced by the N-sector is the sum of three components, *viz:* (*a*) autonomous de-

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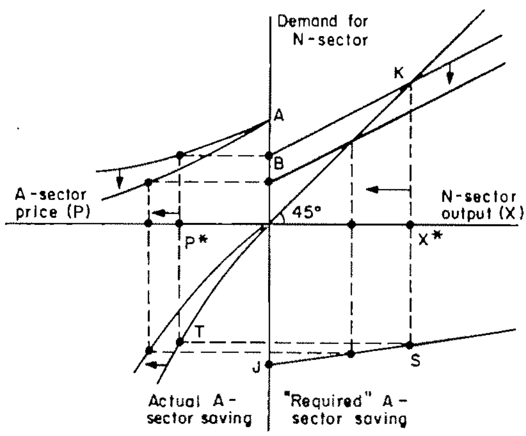

Note: A two-sector model in which the agricultural price varies to clear its market (*A*-sector) while nonagricultural output (*N*-sector) adjusts to meet effective demand. A downward shift in the agricultural supply function leads to less real saving from the *A*-sector and less demand for *N*-sector products, for a given agricultural price. The outcome is an increase in the *A*-sector price, and a fall in *N*-sector output.

Figure 1. A two-sector model

mand for government consumption, investment, and exports, at point *A*. (*b*) Demand from agricultural incomes. This increases with the agricultural price *P*, because of rising farm incomes and price-substitution responses in farmers' demand functions.[1] (*c*) Demand from nonagricultural incomes will fall as *P* rises, for a given nonagricultural output *X*. The stylized fact is that food and most raw material demands are price inelastic; thus an increase in *P* will lead to increases in money outlays for agricultural commodities, and decreases in nonagricultural real income and purchases of nonagricultural goods.

The response to price of the sum of these demands has an ambiguous sign. In the northwest quadrant of figure 1, we have shown the income effect in demand from nonagricultural incomes as dominant, so that as *P* rises, demand for nonagricultural products drops off. At price P^*, the market demand facing the *N*-sector (at zero level of output *X*) is *B*.

Consumption of nonagricultural goods also responds to incomes generated in that sector. For simplicity in the diagram, we assume that the price of *N*-goods is fixed by a constant mark-up over urban prime cost (the short-run numeraire) and also that there is excess capacity in the sector. Its consumption function takes the usual Keynesian form, a straight-line rising function of *X*, beginning for the agricultural price P^* at point *B*. The northeast quadrant is a Keynesian cross, determining equilibrium at point *K* where the consumption function meets the 45°-line. For price P^*, nonagricultural output is pegged at X^*.

Together with the market for nonagricultural goods, the savings-investment balance serves to close the model. The southeast quadrant shows the amount of savings "required" from agriculture (required savings = investment − savings from nonagriculture), a declining function of *X*. For high enough *N*-sector output all autonomous expenditure could be matched by savings from nonagriculture alone, at a point far to the right on the axis for *X*. On the other hand, if *X* fell to zero, agriculturalists could presumably manage to generate all savings required—point *J*. In practice, the economy will lie somewhere between these two extremes. However, with low marginal savings propensities from nonagricultural incomes (not improbable in LDCs), savings supplied from the *N*-sector will not be highly responsive to output *X*. Required savings from agriculture will mostly be determined by investment or, in the representation of figure 1, the trade-off relationship between the two sources of saving will be rather flat.

Savings supply from agriculture will of course rise with the sector's income, as determined by the price (via the supply function). The southwest quadrant of figure 1 sketches agricultural savings as a function of price. Savings-investment balance occurs at the price and output pair P^* and X^* where savings generated from agriculture at level *T* is just equal to the amount required at *S*. From the accounting implicit in the diagram, the agricultural savings will have to take the form of a trade surplus with respect to the nonagricultural sector. The flat curve in the southeast quadrant means that the required surplus in terms of nonagricultural goods is pegged by investment demand. The price *P* (and the terms of trade) adjust to permit the surplus to appear.

The points P^* and X^* in fact represent a full equilibrium in which the commodity market and savings-investment are both in balance. The two equilibrating processes can be summarized in one diagram, by consolidating the upper and lower quadrants of figure 1 sepa-

[1] Very strong income effects in farmers' demand for their output could make their nonagricultural purchases fall as *P* goes up. In the present model we assume away this marketed surplus problem, though it is central to the model of the sections below.

rately. On the savings-investment side, the southeast quadrant shows that required agricultural savings is a declining function of X. On the other hand, savings supply from the A-sector rises with P. Thus, in equilibrium an increase in P has to be accompanied by a fall in X, to keep savings-investment in balance. This relation is drawn as the "Saving-investment" curve in figure 2.

The story in the commodity market is slightly more complicated. As figure 1 is drawn, an increase in nonagricultural output (determined by the Keynesian cross in the northeast) will have to be accompanied by a fall in P. The dominant mechanism is the income effect in nonagricultural commodity demand—a decrease in P raises nonagricultural real incomes enough to stimulate overall demand for X. Again we derive a negative relationship between P and X. For stability, the slope has to be less steep than in the savings-investment balance, as shown by the "Commodity market" line in the left-hand diagram of figure 2.

The other possibility is that increases in P will stimulate aggregate demand for X, via rising farm incomes. This case is more likely when the agricultural sector is large relative to nonagriculture and is illustrated by the rising "commodity market" line in the diagram to the right in figure 2.

Comparative Statics of Output Levels and the Terms of Trade

Changes in policy or exogenous variables can be viewed as shifting one or more of the curves appearing in figures 1 and 2—the diagrams show how agricultural price and nonagricultural output adjust to re-establish a disturbed equilibrium. We work through several examples in this section. They reveal that interactions between sectors hold enough potential surprises to keep the macropolicy team alert.

First, figure 1 itself demonstrates what happens when there is a downward shift (due to bad weather, say) in the agricultural supply function. For a given agricultural price, agricultural income will be lower because of the loss in output. There will be both less savings and less demand for N-goods originating in the A-sector, causing the curves in the northwest and southwest quadrants of figure 1 to shift toward the horizontal axis. Tracing around responses in the diagram (beginning at point S, say) shows that P must rise and X fall in the new equilibrium—the whole graphical structure is displaced to the left. The adjustment mechanism is the slide downward of the demand curve in the northeast quadrant—aggregate demand is reduced by the income loss attendant upon falling agricultural supply.

The sort of supply shock shown in figure 1 easily can set off a burst of inflation, if money wages respond to the rising agricultural price and (as discussed in more detail below) drive up N-sector costs in turn. A sequence of such shocks could keep inflation going if, for example, population growth runs ahead of the growth rate of agricultural supply. To deal with such a process formally would take us too far afield, but the reader will recognize its affinity to the Structuralist inflation model that Sunkel first proposed.[2]

A second set of implications can be drawn regarding agricultural trade. For simplicity, assume that imports come in under a quota or exports go out through a marketing board; in effect, the government regulates the quantum of trade. In figure 1, the upper quadrants will not be affected by changes in trade policy, because they relate internal incomes and prices to N-sector demand. In the lower quadrants, however, required saving from agricultural income will react to trade policy shifts. An increase in agricultural imports or reduction in exports, for example, will lead to an *ex ante* increase in the trade deficit or foreign saving and a reduction in A-sector saving required. As shown by the shifted "savings-investment" curves in figure 2, a lower level of X (and N-sector saving) is then consistent in equilibrium with a given P (and agricultural saving). The final outcome depends on whether N-sector demand responds positively or negatively to P. In the latter case (where N-sector income effects are important), an increase in agricultural imports will cause P to fall and generate enough demand to lead to an increase in X (left side of figure 2). Both changes would favor urban dwellers, under conditions in which their share in economic activity (and N-sector demand) is large. In the circumstances, a political coalition in favor of gaining easy access to imports could form. Examples might be the groups favoring repeal

[2] See the paper by Eliana Cardoso for an elegant description of a Sunkel-type inflation in an independent development of essentially the same model as in figure 1. Taylor provides additional background.

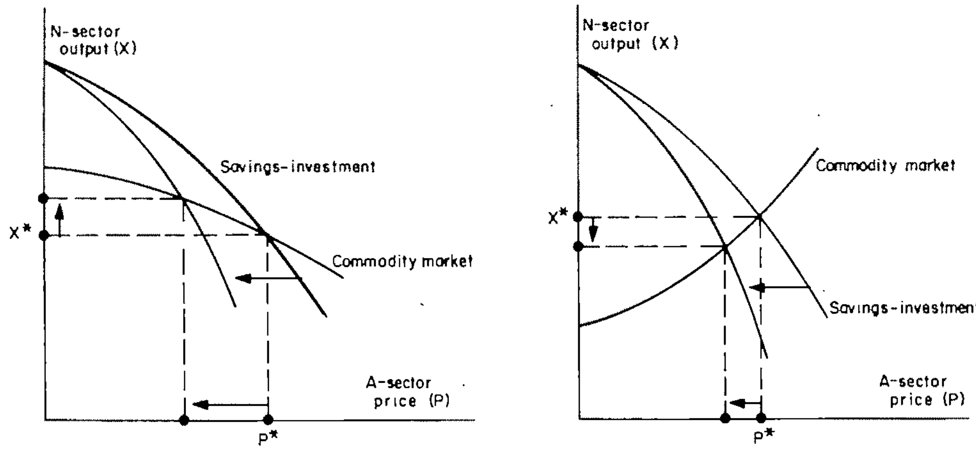

Figure 2. Model of the agricultural and nonagricultural sectors expressed in terms of equilibrium (P, X) combinations in the nonagricultural commodity market and the savings-investment balance

of the Corn Laws in England in the last century, or the domestic supporters of low-cost Japanese acquisition of rice from Taiwan and other locales before World War II. By contrast, in the large-agriculture case, shown to the right in figure 2, the increase in imports causes P and X to fall. Liberal import policies might be opposed by most domestic interests in this case, whereas only agriculturalists are penalized in the situation at figure 2's left.

Increases in exogenous demands for nonagricultural goods generate a third comparative static tale. The analysis is a bit tricky, so we take it in steps.

The initial impact of the demand increase is to shift both autonomous demand for nonagriculture (point A in figure 1) and the base level of required agricultural savings (point J) away from the origin. Assume for a moment that demand for nonagricultural products is independent of P. Then the demand increase will lead to a higher X from the Keynesian cross in the northeast. The subsequent impact on required agricultural savings in the southeast appears to have an ambiguous sign, because X rises (lower required savings) but J moves away from the origin (higher required savings for a given X). However, the problem vanishes when we recognize that the demand response in the northeast is subject to an expenditure leakage that does not matter in the southeast. The Keynesian cross shows multiplier demand stimulated by X for itself, after demand for agricultural products from nonagricultural income is netted out. The southeast quadrant shows the gap between investment and overall savings from incomes generated by X. The difference shows up in a positive response of required savings—and thus of P—to the increase in autonomous demand.

Now reintroduce the dependence of N-sector demand on P. By LeChatalier's principle, a positive relationship means that the increase in X just discussed will lead to further demand increments through the price mechanism, so the initial increase in autonomous spending will be reinforced. On the other hand, a negative relationship between P and demand (as actually shown in figure 1) will dampen the initial increase in X, and might even leave a final negative effect of autonomous spending on nonagricultural output. This extreme response is unlikely, but the analysis does show that when agricultural products are a large part of the consumption bill of a non-negligible urban population, then weak or ambiguous output responses to fiscal initiatives may be the rule. Semi-industrialized countries are particularly prone to such ills.

A fourth story is based on an increase in the marginal propensity to consume from nonagricultural incomes, for example, from an income distribution shift. For given levels of autonomous spending and the agricultural price, the demand line in the northeast quadrant of figure 1 becomes steeper, leading to an incipient increase in X. In the lower quadrants, the result would be a fall in required agricultural savings and P, if the response curves stayed put. However, the increased propensity to consume will lead to a lower propensity to save, and the required agricul-

tural savings curve in the southeast would flatten out. The flattening, in fact, would be strong enough to lead to a higher agricultural price, for the reason sketched above—part of the consumption increment in the northeast quadrant leaks to demand for agricultural commodities, while the whole effect is captured in the savings response below. In the northwest quadrant, the price increase would lead to additional demand for nonagriculture if it responds positively to P, or dampen the initial impact in the opposite case. Once again, income effects can foil the expansionary impact of an increase in the nonagricultural propensity to consume. But prices will rise regardless of the output response.

Finally, consider an increase in the urban money wage. From the assumption of mark-up pricing, the wage increase will drive up the price level, perhaps after a lag. For an unequal urban income distribution (as postulated by Kuznets and—indeed—Lewis) it also may increase the overall propensity to consume, as the wage bill rises relative to total profits and import costs.

We can decompose the effect of the wage increase, using results previously derived. The nonagricultural price increase cuts back on the purchasing power of agriculture, shifting the curves as in the left-hand quadrants of figure 1. Hence, we would expect the agricultural price to rise and nonagricultural output to fall from the wage increase.

At the same time, the nonagricultural propensity to consume goes up. As just discussed, P will be given another upward nudge, but the output response can have either sign. In sum, the wage increase will lead to higher prices in both sectors, but output can shift either way. In at least one empirical model embodying agriculture/nonagriculture interactions of the type stressed here, an urban wage increase leads output to expand (see McCarthy and Taylor). The rising wage offsets the loss in aggregate demand implicit in any downward shift in the agricultural supply function, but only at substantial inflationary cost. The dilemma posed by the structuralist inflation model sketched above begins to bite.

Economic Dualism, Marketed Surplus, and Trade

The model just described lets the agricultural price vary to clear the market, with income distribution shifts between the sectors bringing aggregate demand in line with supply. Now we take a somewhat longer term perspective, in which technological conditions, factor supply functions, and patterns of demand dictate economic response. Specifically, we consider an economy in which there is technological dualism in the sense of wide differences in technique between the sectors (with the capital-labor ratio being substantially higher in nonagriculture), surplus labor due to a highly elastic labor supply function, and heavy concentration in demand from labor incomes on agricultural (or food) commodities. Largely to avoid unilluminating mathematics, labor and capital are assumed to be freely shiftable between the sectors, and fixed coefficients for these inputs characterize technology in production. The model thus is based on assumptions stressed by Lewis and Eckaus.

Sectoral interactions are easily described using standard results from the theory of international trade. Let the nonagricultural price be the numeraire. Then by the assumption that agriculture is labor-intensive, an increase in the agricultural price P will increase the wage w and lower the profit rate r. The real wage in terms of food ($q = w/P$) is also an increasing function of P, on Stolper-Samuelson lines. However, as P rises it has an increasingly weaker positive effect on q (the second derivative is negative), due to a rising relative cost of capital inputs. (See Chichilnisky for a proof, as part of a full formal development of the model.)

By the surplus labor assumption, the increase in q in response to P will pull more workers into production according to the labor supply function.[3] But since agriculture is labor-intensive and the capital stock is fixed, total agricultural output will increase by the Rybczynski theorem. The mechanics are illustrated in figure 3. A rising agricultural price provides more labor along the curve in the southwest quadrant, which in turn stimulates an increase in agricultural output (Z) in the southeast. Reflection around the 45°-line in the northeast quadrant allows measurement of Z on the vertical axis pointing up. Reading the diagram in reverse shows that an increase in demand for Z (for export, say) would have to

[3] Figure 3 is drawn assuming an inverse supply function of the form $q = q_0 + \beta L$, where q_0 is the "subsistence" real wage at which no employment would be forthcoming, and L is total employment. In a surplus labor situation, the coefficient β will be very small.

be accompanied by more employment and a higher agricultural price.

So far, so good: agricultural supply response depends on price in a dual economy. But nothing has been said regarding how the extra labor income from more A-sector output gets spent. Suppose that a large share of the increment goes toward purchases of agricultural goods. Demand mirrors the increases in employment and output, so that excess agricultural supply after sales for personal consumption may not be very price responsive at all. The northwest quadrant of figure 3 illustrates a case in which around 90% of wage income is spent on "food." The example is exaggerated, but does illustrate for the two prices traced around the quadrants how A-sector output minus demand increases only slightly as the price P is doubled. Indeed, at higher levels of P the excess supply response may even be perverse. When restated in a plausible though simplified general equilibrium model, the traditional marketed surplus problem is far from being as trivial as it sometimes has been made out to be.

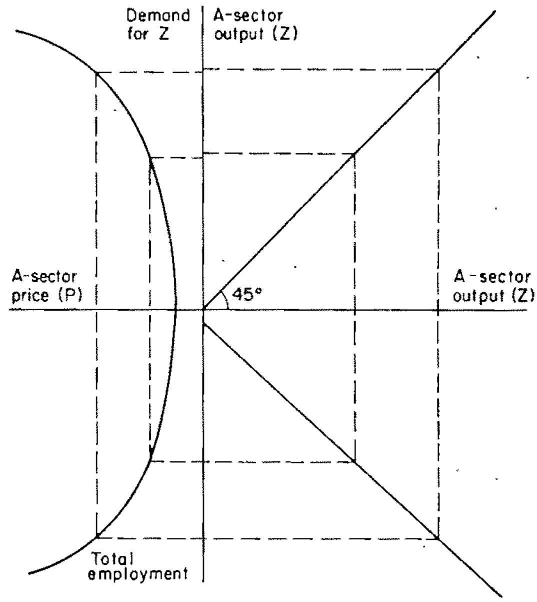

Figure 3. Impact of changes in the agricultural price on the sector's excess supply in a model with highly elastic labor supply, production dualism, and a large share of wage income devoted to food

Marketed Surplus Woes

Figure 3 illustrates an income distribution problem faced by countries in which the wage good is used for export. An increase in the price to call forth extra supply is frustrated, because the extra income resulting from increased production largely goes to wage good demand.

Policy choice under these circumstances is difficult, as experience in a number of countries suggests. When the agricultural product is exported (wheat or beef in Argentina, rice in Thailand) the government often tries to drive a wedge between the acquisition and sale price of the wage good, to cut real consumer income and demand while maintaining supply. Such policy may fail on other grounds, however. An example is increasing resistance on the part of profit-income recipients to shifting the income distribution toward agriculture via the high supply price. More generally, the economic system is Walrasian unstable (or nearly so), which makes management via the price system a delicate task.

Even in a closed economy, where the wage good is not traded and A-sector demand must equal supply, similar problems arise. For example, an increase in the capital stock will shift the intercept of the line in the southeast quadrant of figure 3 away from the origin.[4] For a given employment level, the diagram shows that the result would be a decrease in agricultural supply as resources move toward the capital-intensive, nonagricultural sector. With demand limited by supply the agricultural price P would have to fall to reduce labor income (northwest quadrant), leading via a lower real wage to decreased labor supply in the southwest. After subsequent rounds the process could converge at a lower (or at best slightly higher) level of employment overall.

What these results show is that internal demand conditions do not permit easy absorption of the capital-intensive good. In Eckaus's terminology, there is a "factor proportions" problem, exacerbated by patterns of demand. A bowdlerized Marxist interpretation would be that surplus from nonagricultural production cannot be realized. Confiscatory income realignments against wages by a government favoring nonagriculture would shift the demand curve in the northwest quadrant toward the horizontal axis, and permit realization to

[4] The intercept represents the level of employment when agricultural output is zero and all available capital is used to produce the nonagricultural good.

occur. An example would be state purchases of the nonagricultural good financed by a levy on labor income. The Stalinist resolution of this set of difficulties (first enunciated by participants in the Soviet industrialization debate of the 1920s) might be interpreted along these lines.

Problems with Policy Change

The problems raised by the dual economy model could be pursued further. For example, its potential Walrasian instability can be countered by the government acting as a Marshallian stable purchasing agent, as explored by Chichilnisky. Similarly, if the supply of capital is also price-sensitive, the transformation curve between agriculture and nonagriculture can cease to be concave to the origin—see Chichilnisky and Heal. These difficulties ultimately arise from production dualism, factor supply functions, and demand behavior, all tending to destabilize the system in the same way.

Somewhat similar observations apply to the model discussed in the first two sections of this paper. The relative price insensitivity of food demand and the role of agricultural incomes as a savings source go together there to generate potentially perverse responses to standard policy ploys. In particular, agricultural supply shortfalls may be highly inflationary, fiscal spending may not stimulate aggregate demand, extra food imports will have strong effects on the intersectoral income distribution, and demand may react positively to an increase in the money wage.

The implications of these results for policy are sobering, insofar as the models adequately replicate sectoral interdependencies in real economies. In a two-sector framework, modest ingenuity suffices to generate difficulties of the type emphasized here. The question is whether or not the models capture slices of likely economic response. Our view is that they do, and that the problems faced by policy makers in poor countries are economically real and severe. But we would be delighted if we were wrong and would welcome demonstrations that such is the case.

References

Cardoso, Eliana A. "Food Supply and Inflation." *J. Develop. Econ.*, in press.

Chichilnisky, Graciela. "Terms of Trade and Domestic Distribution: Export-Led Growth with Abundant Labor." *J. Develop. Econ.*, in press.

Chichilnisky, Graciela, and Geoffrey Heal. "Welfare Economics of Competitive General Equilibrium with Variable Endowments." Mimeographed. Dep. Econ. Disc. Pap. No. 18, Columbia University, Aug. 1979.

Eckaus, Richard S. "The Factor Proportions Problem in Underdeveloped Areas." *Amer. Econ. Rev.*, 45(1955):539–65.

Kuznets, Simon S. "Economic Growth and Income Inequality." *Amer. Econ. Rev.* 45(1955):1–28.

Lewis, W. Arthur. "Economic Growth with Unlimited Supplies of Labor." *Manchester School of Econ. and Soc. Stud.* 22(1954):139–91.

McCarthy, F. Desmond, and Lance Taylor. "Macro Food Policy Planning: A General Equilibrium Model for Pakistan." *Rev. Econ. and Statist.*, in press.

Rybczynski, T. N. "Factor Endowments and Relative Commodity Prices." *Economica* 22(1955):336–41.

Stolper, Wolfgang E., and Paul A. Samuelson. "Protection and Real Wages." *Rev. Econ. Stud.* 9(1941):58–73.

Sunkel, Osvaldo. "Inflation in Chile: An Unorthodox Approach." *Int. Econ. Pap.* no. 10(1960), pp. 107–31.

Taylor, Lance. "IS/LM in the Tropics: Diagramatics of the New Structuralist Macro Critique." Paper presented at a conference on economic stabilization in less developed countries, the Brookings Institution, Washington, D.C., 25–26 Oct. 1979.

Food System Organization and Performance: Toward a Conceptual Framework

James D. Shaffer

My purpose is to explore some ideas and problems concerning a conceptual framework for organizing knowledge of the relationship between political-economic organization and performance, with application to the U.S. food system. The connection with post-Keynesian economics is that of a common belief that existing paradigms are inadequate to inform some critical economic policies, especially those involving stagflation. This is stimulating a reexamination of assumptions about important variables and relationships. Most notable is the examination of the role of the market and the micro-macro relationships (Galbraith 1978).

I put the paper in the context of the program of research on "Organization and Control of the U.S. Food Production and Distribution System" established as regional research project NC 117. The general objective of the project is ambitious: to describe the existing organizational system for producing and distributing food products, to identify the economic and institutional forces that are changing this system, to forecast where present trends may lead, to set forth alternative public policies that could affect the system of the future, and to appraise the alternatives in light of the values and goals held by the various sectors of the population.

Work to date on the project has been organized along three general lines of inquiry: (*a*) industry studies, i.e., food retailing, (*b*) studies of subsectors and vertical coordination systems such as the dairy subsector, electronic exchanges, and procurement practices of retailers, and (*c*) studies of the legal environment such as antitrust laws applied to the food system.

The analytical framework has been eclectic. Industry studies have tended to be conceptually organized by the Industrial Organization framework (IO), which is a structure-conduct-performance (S-C-P) paradigm grounded in price theory. The subsector studies have paid more attention to the internal decision making of the firm and thus draw from work in organizational behavior. The dominating framework of the group has been an expanded S-C-P. The basic concept of the paradigm is that market structure strongly influences market conduct of firms which in turn influences market performance. Market structure variables include number and size distribution of firms, entry conditions, and product differentiation. Market conduct refers to pricing policies, sales promotion actions, decisions on product characteristics, and actions by competitors to coordinate market behavior. Market performance is concerned with allocative and technical efficiency, progressiveness, product characteristics, and equity (Marion and Mueller). The extended S-C-P framework looks at the influence of government programs and regulations on market structure, conduct, and performance and expands the notion of performance to a more aggregate system concern with such outcomes as income distribution, employment, inflation, level of living, and the distribution of economic and political power.

All models necessarily abstract from the conditions of the real world. The S-C-P framework tends to omit aspects of reality I would like to stress in attempting to extend the scope of the paradigm. The IO model attempts to explain the conduct of firms by concentrating on the competitive environment and other economic conditions external to the firm such

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as the characteristics of demand and technology. The basic unit of analysis is the "relevant" market. The firm is treated as a "black box." At the same time, an extensive literature has developed dealing with intrafirm decision making and the behavior of organizations which has had little influence on price theory and other economic analysis. Babb and Lang have explored the implications of this work for research on the food system. By avoiding consideration of firm decision making, IO tends also to avoid the problem of uncertainty. Thus, the pervading problem of coordinating economic activity, investing, and producing in one period to meet demand in future periods, is generally external to the model. Finally, the performance of the food system depends upon the behavior of many organizations including governments, households, and associations of firms. I would like to explore a framework which would consider at least some aspects of this reality.

The extended S-C-P framework has contributed to valuable research. Marion and Mueller provide an insightful discussion of research on the food system from this perspective. My hope is to encourage additional conceptual work which will help with the type of analysis implied by the objective for the NC 117 project.

General Approach

Start with the most elementary and global concept. At a point in time participants in a political economy exist in an environmental situation which is their opportunity set. Each participant responds to his environmental situation and the aggregate consequence is a change in environment. The changes in the environment contain the benefits and costs for individuals and groups which follow from the behavioral responses. Changes in participants' perceptions of the environment and appropriate behavior follow from the change in the environment. The sequence continues, the system evolves. Call the total flow of consequences which follow from the organization of the political economy, performance. Then we can say that the evolving system is driven by this basic three-term sequence of environment, behavioral responses, and performance—E-B-P . . . E-B-P . . . .

Obviously, no conceptual framework can deal with the complexity implied by this three-term sequence. The task is to classify strategic characteristics of the environment, classify participants and their behavioral modes, classify outcomes, and develop meaningful hypotheses about their relationships.

Environment

The environment can be thought of conceptually as overlapping opportunity sets. The physical environment, or aggregate physical opportunity set at any one time, sets the outer bound of the possible payoff matrix for society as a whole. The political-economic system structures relationships among participants, thus structuring the opportunity set for individuals and groups by defining rules for access to resources and payoffs from the aggregate opportunity set. An individual opportunity set is a function of location in the political economy. The individual participates in the political economy as a member of organizations—governments, firms, households, and other associations. Thus, his opportunity set is governed by the external environment and the internal structure of the organizations and his positions.

Individuals articulate preferences, that is, seek their goals, through market, political, and social transactions. Transactions carry information, influence, benefits, and costs. Transactions take place within organizations and between organizations. A fundamental issue in political economics is the determination of the mix between market and political processes for preference articulation.

The external environment of organizations includes: (*a*) factor and product markets, which would include the extent and product content of the market plus all of the variables considered part of structure in the S-C-P framework; (*b*) the system of rights and regulations, broadly defined, which includes property rights, enforcement of contracts, all economic regulations, taxes, and subsidies; (*c*) perceived social and political pressures and expected markets, which introduces the idea that organizations respond to perceptions of the future. This includes the influence of ideology—a general agreement about acceptable behavior. Behavior outside of the prevailing ideology implies the possibility of sanctions and is a pervasive constraint, and (*d*) the technical transformation functions.

Performance

In the dynamic framework, performance is a complex concept. Performance is the outcome of the behavior of the sum of participants acting within the constraints of their perceived individual opportunity sets. The aggregate consequences are the changes in the environment. The changes include both the physical environment, i.e., production and consumption, and change in the political-economic structure. The outcome of one period is an input to subsequent periods. The outcome contains the distribution of costs and benefits to the participants. The expected distribution of benefits and costs contains the incentives for the behavior. Among the consequences is the change in perceptions and preferences of participants influenced by this experience.

Now comes a fundamental problem of the political economy and of organizations. The individual participant is exposed to only a small portion of the aggregate opportunity set, and only some of the consequences of behavior accrue to the individual. That is, the individual acts on the environment in terms of his perceptions of the consequences. Perceived consequences that will be most immediate and act as incentives usually will be those that fall directly on the participant and are linked directly to specific behavior. The management system of an organization is intended to structure individual opportunity sets, incentives, and sanctions in such a way that individual behavior is congruent with the objectives of the organization.

This pervasive problem is recognized in part in economics in such concepts as market failure, externalities, free riders, and public goods. Schmid provides an in-depth study of the problem of external consequences in public choice. Shaffer (1979) looks at regulations from this perspective.

For the political economy the combination of the market and regulatory system structures what consequences of behavior are taken into account by firms and other participants. Actions through both the political system and the market alter the aggregate and individual opportunity sets. That is, the available factors, products, and incentives are influenced. The opportunity set of each individual is coercive. It rewards and punishes and thus channels behavior.

Time and uncertainty create many problems in structuring individual opportunity sets through regulations and markets in such a way that consequences of individual behavior are congruent with goals. Actions and consequences are separated by time, and direct connections are difficult to establish. The future payoffs from actions are uncertain, future preferences are uncertain; uncertainty is pervasive. Political-economic activity involves complex sequences with complex patterns of uncertain consequences. Understanding such sequences is the interesting challenge of political economics.

One of the problems in public policy is to identify relevant classifications of performance. The definitions of both relevant dimensions of performance and performance indicators are conceptual problems and such concepts would be an important part of a fully developed conceptual framework. Among those considered important are total production, product mix, employment, inflation, and distribution of benefits. Many other consequences are important but lack performance indicators.

Behavior

The link between political-economic organization and performance is the behavior of individuals and organizations. We need to incorporate concepts about behavior into the conceptual framework to form the basis of realistic assumptions for theory development and for practical policy analysis. My basic assumption is that individuals search narrowly selected portions of the environment and identify patterns of behavior consistent with their perceptions of that opportunity set which will satisfy them. Thus, I suggest starting with the concepts of satisficing behavior and bounded rationality. Simon, in his Nobel lecture, eloquently supports the incorporation of these concepts in the theory of decision making in firms and administrative units. He assumes the decision maker has limited capacity and operates in an uncertain environment. Among the procedures adopted to solve problems is to look for satisfactory choices rather than optimal ones, replace abstract goals with tangible ones, and divide up the decision-making task among many specialists.

I assume the participant develops multiple goals and many techniques to satisfy the goals. Techniques are patterns of behavior, adaptive and strategic, which are perceived as appro-

priate in dealing with particular situations embedded in the individual's perceived opportunity set. Perception is selective and influenced by experience. The technique may or may not be effective (optimal) behavior given the objective environment.

Techniques will include (*a*) the opportunistic behavior—"self-interest seeking with guile" suggested by Williamson (p. 26) as "having profound implications for choosing between alternative contractual relationships"; (*b*) decision processes similar to maximizing processes often assumed in economics; and (*c*) the behavior of Hirschman's slacker.

Much conceptual and empirical work remains to be done in incorporating learning, decision making, and search processes into a political economic framework. I am impressed with some of the insight from the concept of contingent reinforcement which forms the basis for a theory of learning (Platt). This involves a three-term sequence (situation-behavior-reinforcement) and could be interpreted to a statement such as: At any particular time an individual is in a situation, responds to it by changing the environment, and the change in the environment influences (reinforces positively or negatively) the individual's future behavior, he learns. He learns techniques or complex patterns of behavior as a result of payoffs from the environment. The payoffs (reinforcers) are contingent on particular patterns of behavior.

However, this theory is, I believe, too limiting for our understanding of political-economic behavior. It is useful to think of economic behavior in terms of goals, preferences, plans, expectations, etc. while recognizing they are all learned, including learning from communication, cognition, and especially imitation.

Collective Action

Participants seek their goals primarily in environments of collective action and decision making. The primary types of organizations in the political economy are firms, households, unions, and governments, although many other types of associations are also important. These organizations shape the opportunity set of their members and the interaction of organizations shapes the opportunity set of the organizations.

What differentiates this aspect of the E-B-P framework is the proposition that participants have individual and different perceptions about appropriate behavior to achieve general goals of the organization and have personally held preferences they will seek to articulate within the opportunity structure of the organization. The behavior of the organization follows from the political interactions of the participants and there is no meaningful objective function for the organization independent of this political process. It is further assumed (as does Leibenstein) that each participant has some discretion in the amount and in the application of effort, and no one in an organization knows with certainty the consequences of the collective decisions.

In this section I first suggest a tentative analytical framework for examination of participant behavior in organizations in general and then briefly comment on a few characteristics of firms, households, and government. Finally, I comment briefly on the market as a coordinating mechanism.

Organizations

The conceptual framework identifies four classes of variables which influence the behavior of the organization: the external environment, the organizational structure, the organizational control procedures, and individual perceptions and preferences (see Roberts).

The external environment of an organization was discussed previously. It represents the opportunity set for the organization and thus disciplines the behavior of the organization. The aggregate benefits available to members depend upon the collective ability to exploit the organization's opportunity set.

The organizational structure defines the roles of participants and the resources available to carry out the tasks identified with the roles. The structure defines jurisdictional boundaries, lines of communication, and authority. It is the basic structure in which transactions and decision processes take place. Roles are always incompletely specified.

Cyert and March, in their pioneering work, emphasize the concept of standard operating procedures (SOP). In order to reduce transaction costs in decision making, the group develops SOPs. These are generally accepted rules of thumb for the operation of the firm. The SOPs are political solutions reconciling the difference in perceptions and preferences

of the various participants. As long as the goals of members of the group are satisfactorily met, the SOPs are retained. If target goals are not met, participants have an incentive to search for new patterns of behavior that better meet the targets. SOPs vary from complex decision trees to rules for delegating authority and rules for responding to other firms' actions. Knowledge of a firm's SOPs could provide the information for simulation models to predict firm behavior.

The control system consists of the rewards and punishments associated with decisions and effort. The contingencies are embedded in compensation, promotion, and retention practices as well as in peer approval. The ability of top management or leaders to impose their goals on the organization is a function of the effectiveness of the control system. The external environment, organizational structure, and the control system shape each member's opportunity set.

Individual objectives and beliefs determine how members respond to their opportunity set within the organization. Beliefs and goals are not independent, however. They are influenced by a socializing process within an organization, which may be a significant influence on patterns of behavior.

Firms

The basic concept of the firm is that of a bureaucratic organization of members with disparate goals and individual discretion, within limits, operating under conditions of great uncertainty. It is hypothesized that variation in behavior and performance will be associated with the size and structure of firms, with the goals of the participants, and with the discipline imposed by the external environment.

A dynamic framework must also consider the interaction of the firm with the external environment. The extent of participant discretion is affected by the capacity of the firm and its participants to shape or protect themselves from the external environment. It is assumed that investments will be made to influence both the regulatory system and the market. Through collective action or custom, classes of participants acting across an industry insulate groups and practices within firms from the discipline of the market—for example, unions establish work rules, accountants have standards, and many decisions are based on industry-wide standards.

Galbraith (1967) argues that large-scale enterprise is a technological imperative. Investments pay off over a long period, and in order to protect such investments the technostructure attempts to reduce uncertainty by obtaining a measure of control over the external environment through vertical integration and contracts for inputs and products, influencing demand by advertising, stimulating government purchases, sheltering the firm from the uncertainty of capital markets through retained earnings obtained in oligopolistic markets, and influencing the regulatory system.

Williamson provides an insightful analysis of the incentives for firms to integrate vertically and thus grow. He emphasizes uncertainty of markets and the incomplete nature of contracts. Bringing an activity within the firm deals with problems of information impactedness, among others. Williamson argues this phenomenon is more important than the technological imperative in explaining firm size.

Firm growth is a powerful dynamic force if the objective is to gain control over the external environment. The greater the size, the greater the capacity for political and market influence. If size also allows greater firm member discretion, and individual rewards to managers are related to size, the incentive is reinforced.

The concepts of organizational slack—payments to firm members in excess of what is required to maintain the organization, as developed by Cyert and March, and X-inefficiency (Leibenstein, pp. 76, 79), roughly the deviance of a firm's performance from that which could be accomplished within its external opportunity set—represent phenomena and lines of inquiry of great significance for system performance. For example, based upon his analysis, Leibenstein concludes: "1) the cost of a commodity is not independent of the price of the commodity; 2) except in extreme circumstances firms do not minimize costs; 3) cost of production has a tendency to rise toward the price level; and 4) there is no production function independent of the environment of the firm and the history of the firm" (1976, pp. 492–93).

Organizational slack, however, has important economic functions. In an uncertain world, firms make many mistakes and must deal with unforeseeable situations. If firms went out of business with every adversity, the economy would be in chaos. Hirschman argues that loyal or inert customers contribute to

slack and that slack is necessary to allow firms time to recoup from temporary poor performance.

Households

Household behavior can be analyzed within the same general framework as other organizations. A multiperson household, for example, will develop specialized functional roles. Typically, this will include a purchasing agent with perceptions and preferences differing from other members. Transactions between the purchasing agent and other members will lead to an acceptable set of SOPs for purchasing, and specific products will become embedded in other SOPs and individual techniques. An example of a consequence of this fact is that prices of products may vary within a range without response. That is, there will be a price threshold. Thus, an existing price represents a unique point on a kinked demand curve. And when a price change is sufficient to cause a reevaluation of related SOPs, a new purchase pattern resistant to change will develop. Thus, a change in price can result in a shift in a household's demand curve. Household behavior is influenced by advertising and other promotion practices and by the mix of products made available. Endogenous preferences are part of the dynamics of the system.

Government

We are interested in governments as mechanisms for the articulation of preferences and as bureaucratic organizations for implementing policy. The conceptual framework for organizations generally applies. Governments are made up of participants with goals of their own operating under conditions of great uncertainty. Elected officials are uncertain about the preferences of voters and uncertain about the consequences of their own actions. Votes often carry little information. Thus, the external environment of a governmental unit often provides a very nonspecific discipline. The discipline is similar to that of stockholders over a large corporation. The economics of political influence is an important aspect of preference articulation. Elected officials have limited capacity to impose their preferences on the bureaucracy. Implementation of policies and programs depends upon the effectiveness in shaping the opportunity sets of the participants. The effectiveness of government depends heavily on the ideology and strategy of the agency.

Government and markets are joint mechanisms for articulating preferences. Government produces the regulatory system shaping the opportunity set of firms and households. This determines what has to be taken into account by participants. The regulatory system sanctions a pattern of private power including facilitating and limiting collective action. In this sense, markets deal only with solved political problems, and the market is an instrument of the regulatory system.

The Market

The genius of the market as a social institution is that it provides a mechanism for collecting and summarizing an enormous quantity of idiosyncratic information about the environment and preferences in an easily understood form (prices), which at the same time carries incentives to produce and conserve to the participants of the system. The political economic problem is to institute the regulatory system in such a way that price carries the information and incentive, as consistent as possible with preferences for system performance and the reality of the environment. Two marginal comments: (*a*) market power is the ability to influence opportunity sets and is a function of the market structure and political influence, and (*b*) trading is usually between agents who have some discretion.

The Food System

Meeting the objectives of the NC 117 project requires (*a*) a description of the food system, (*b*) some understanding of the evolution of the system, (*c*) a means of identifying performance, (*d*) a capacity to design policies and programs to achieve specific performance norms, and (*e*) a means of predicting the consequences of specific programs and policies. This section includes brief comments related to these tasks and a few conceptual and practical issues.

First, we have a conceptual problem in defining the U.S. food system and, thus, the scope of the project. I propose a broad definition, not suggesting that it is possible to direct research to the whole, but to provide a context for the inquiry.

Start with the concept of a systems model which would provide a simplified description of that part of the world that has an interdependence with production, distribution, and use of food in the U.S. The striking reality is that much of the world's political economy and ecology influence, or are influenced by, these activities. An industrialized food system uses inputs which originate in every corner of the globe. U.S. food input and product markets are affected by public policies and organizational behavior of many countries. Chemicals used to produce U.S. food enter the ecological system of the entire world and deplete world resources. Many multinational and conglomerate firms supply inputs and process and market food.

Policy Design

To evaluate alternative policies, it is necessary to predict the way in which the policy will alter the opportunity sets of the relevant participants, the consequence that will have on behavior, and in turn on performance. This means attention must be paid to the details of the policy design.

The implementation procedures must be included in policy design and evaluation and must be based on predicted responses of both public and private participants. For example, developing a workable approach to protection from toxic substances in food depends upon knowledge of SOPs of users and behavioral interactions between inspectors and users.

Policy making is an evolving process. It is necessary to develop a feedback and monitoring process for the system. Developing performance indicators is critical to the process, and the design of the indicators is a major conceptual task. For a useful discussion of problems in translating global notions about performance of the food system into policy relevant indicators, see Jesse.

Evolving Structure

A key to projecting changes in food system organization is an understanding of the processes of firm growth, including incentives for vertical integration. Many hypotheses might be suggested. An especially intriguing question relates to the concept of opportunistic behavior. What is the consequence for the structure and performance of the food system of market participants operating from different ethical standards?

The recent interest in farm structure would be informed by an understanding of the changing structure of the food system. What has been taking place is the shift of functions from the farm firm to nonfarm firms, many of them large conglomerates. Of the total value added in the U.S. food system, probably less than 10% is accounted for by on-farm activities.

The complexity of the evolving structure is illustrated by the observation that the largest grain handler in the world (Cargill Grain) operates the largest beef feeding organization (Caprock Industries) which sells to the second largest beef processor and wholly owned subsidiary of Cargill (MBPXL) which markets a large proportion of its product through contractual agreements to the largest fast-food chain (McDonald's) (adapted from Richardson).

Preference Articulation

Preference articulation refers to the processes by which preferences are expressed and taken into account. This includes the ability to satisfy preferences within an existing opportunity set and influence the content of future opportunity sets. The effectiveness of the food system as a mechanism for preference articulation is the key question about the system performance. The effectiveness of preference articulation is a function of the behavior of firms in searching both the preference and physical opportunity sets, the behavior of households in transmitting information and influence, and the responsiveness of government.

Our attention is directed to problems where the system as instituted is either a barrier to effective preference articulation or fails to facilitate preference articulation. These include the basic micro-macro problems where individuals following their own immediate interests lead to long-run consequences inconsistent with the preferences of the group. The missing institution may be the lack of a mechanism for the collective expression of preferences. For example, the local grocery store may have lost out in competition with the supermarket because no mechanism existed for customers to express their preferences for the option to have the store available. Food reliability is a major dimension of performance for the food system, but problems exist in

articulating preferences for the option to have adequate food available at a future date and for food safety. Many dynamic sequences seem to result in outcomes inconsistent with all (or most) participants' preferences. The demise of some light density rail lines serving rural areas is an example. The institution for collective action is missing. Such problems often are identified as market failure, but might better be identified as institutional failure.

Practical policy analysis needs to be directed to the diagnosis of such situations and the identification of the missing institutional mechanism for effective preference articulation.

Equity or justice is a particularly important dimension of performance and must be included in analysis. It is not possible to articulate preferences for equity through the market. Many conceptual problems exist in designing policies to reflect preferences for justice, including the development of performance indicators.

Vertical Coordination

Vertical coordination is a special problem of preference articulation. The issue is the effectiveness of coordination of supply decisions with demand. It deals with the sufficiency of price as a carrier of information and incentives and the behavior of participants in strategic positions. For example, the SOPs and interaction of purchasing agents, merchandisers of large retail chains, and marketing agents of food manufacturers determine to a large extent the characteristics and variety of food products offered to consumers. These practices severely limit the effective access of new products and products from new and small firms. The institutional mechanism for consumers to articulate a choice for a different set of choices is missing.

The cycles in hog and beef supplies and prices are another illustration of the problem in the U.S. food system. There is no evidence that the variation in supplies is related to variations in preferences for these products. The institutions are missing that could provide coordination of current production decisions of producers as a group with future demand. The missing institution may be a system of forward-deliverable contract markets.

Productivity and Costs

If large firms have the capacity to influence prices and members have independent goals and discretion in the firm, then it could be expected that costs would tend to rise to the level of prices. If groups can improve their immediate returns or security by restricting inputs or output and have a collective capacity to do so, productivity will be reduced and costs increased. These phenomena contribute to both lower productivity and a cost-price spiral. This follows from the behavioral model of the firm.

Galbraith and Williamson argue persuasively that large firms seek to protect themselves from uncertainty and that this is necessary. And slack is necessary for survival. But small firms also seek the same protection and for the same reasons. They attempt to accomplish the needed protection from the uncertainty associated with unfettered competitive markets through government programs, collective action, and contracting. Careful analysis is necessary in developing policy to squeeze out "X-inefficiency" to assure that the long-run consequences and trade-offs are accurately assessed.

The argument often is made that regulations reduce productivity and increase costs. Often the regulation simply shifts costs among participants. And thus, the question is, whose preferences should count? However, regulations also often impose unintended and unnecessary costs—the regulation is inappropriately designed. Participants may seek regulation to facilitate collective action that results in reduced output. Union work practices are an example. The missing institution is a mechanism to achieve equity objectives which does not reduce productivity.

Inflation

Inflation is a major problem and NC 117 has been asked to address the issue of the relationship of inflation to the food system. If inflation is a general rise in prices, and firms and groups behave as indicated in the discussion of productivity and costs, and the supply of money is responsive to the demand for money, as it must be, then industrial concentration and the organization of the food system can cause inflation, especially if firm managers are opportunistic. An understanding of inflation thus

requires an understanding of organizational behavior and market structure.

A Final Comment

A practical argument often is made that it is not possible to include behavioral variables in analysis because it is not possible to obtain the data. This is a monumental problem. My argument is that for policy-relevant analysis, we at least need to make assumptions about behavior based on the best data we can get. A conceptual framework that includes behavioral variables generates hypotheses which can at least partially be tested by observable actions of the participants.

Just as bounded rationality is a fact of life in organizations, it is also true for analysts and theorists. We have to recognize the very limited capacity we have for understanding and predicting the behavior of such a complex system. The most unrealistic assumption of all is that of the omnipotent analyst.

References

Babb, E. M., and M. G. Lang. "Intrafirm Decision-Making: Private and Public Consequences." *Future Frontiers in Agricultural Marketing Research*, ed. Paul Farris, in press.

Cyert, Richard M., and James G. March. *A Behavioral Theory of the Firm*. Englewood Cliffs, N.J.: Prentice-Hall, 1963.

Galbraith, John K. *The New Industrial State*. Boston: Houghton-Mifflin Company, 1967.

———. "On Post-Keynesian Economics." *J. Post-Keynesian Econ.* 1(1978):8–11.

Hirschman, Albert O. *Exit, Voice, and Loyalty*. Cambridge, Mass.: Harvard University Press, 1970.

Jesse, Edward V. *Measuring Market Performance: Quantifying the Non-Quantifiable*. NC Project 117 Work. Pap. No. 15, Michigan State University, Mar. 1978.

Leibenstein, Harvey. *Beyond Economic Man*. Cambridge, Mass.: Harvard University Press, 1976.

Marion, B. W., and W. F. Mueller. "Industrial Organization, Economic Power, and the Food System." *Future Frontiers in Agricultural Marketing Research*, ed. Paul Farris, in press.

Platt, J. "The Skinnerian Revolution." *Beyond the Punitive Society*, ed. Harvey Wheeler. San Francisco: W. H. Freeman and Co., 1973.

Richardson, L. "Meat Pricing Dilemma: Can Free Markets Survive Charges of Manipulation?" *Farm Futures*, Nov. 1979, pp. 12–13.

Roberts, Marc J. "An Evolutionary and Institutional View of the Behavior of Public and Private Companies." *Amer. Econ. Rev.* 65(1975):415–27.

Schmid, A. Allan. *Property, Power and Public Choice*. New York: Praeger Publishers, 1978.

Shaffer, James D. "Observations on the Political Economics of Regulation." *Amer. J. Agr. Econ.* 61(Part 2, Nov. 1979):721–31.

———. "Preference Articulation and Food System Performance." Unpublished paper, Michigan State University, 1979.

Simon, Herbert A. "Rational Decision-Making in Business Organizations." *Amer. Econ. Rev.*, 69 (1979):493–513.

Williamson, Oliver E. *Markets and Hierarchies: Analysis and Antitrust Implications*. New York: Free Press, 1975.

The Permanent Income Hypothesis under Rational Expectations

John F. O. Bilson

It is unfortunately true that the most noticeable legacy of the permanent income hypothesis for applied economic research has been to provide a convenient justification for the appendage of a lagged dependent variable to multiple regression equations. Even apart from the fact that a significant coefficient on the lagged dependent variable may reflect serial correlation in the regression errors or the presence of a partial adjustment mechanism instead of the permanent income-forecasting mechanism, the procedure is not a valid test of the permanent income hypothesis because the probable size of the coefficient on the lagged dependent variable is not defined from a prior analysis of the time-series process generating the actual income series. As Muth (1960) demonstrated, the adaptive expectations approach will only provide optimal forecasts of permanent income if the actual income series is generated by a first-order, moving-average process. If this is the case, then the permanent income hypothesis implies a direct cross-equation restriction between the value of the parameter in the time-series process and the value of the coefficient on the lagged dependent variable.

The object of this paper is to describe this manner of testing the permanent income hypothesis and to apply the approach to estimation of the aggregate consumption function in the United States, the United Kingdom, and the Federal Republic of Germany. Although the approach is applied to estimates of the aggregate consumption function, it is readily applicable to demand functions for particular commodities.

The Rational Expectations-Permanent Income Hypothesis

The most common definition of permanent income[1] is that constant level of income (or consumption), y_t^p, which satisfies the intertemporal budget constraint

$$(1) \quad A_t + \sum_{i=0}^{\infty} [E_t\, y_{t+i} - y_t^p](1 + r)^{-i} = 0,$$

where A_t is the predetermined stock of savings at time t; y_{t+i} is the expected level of real income in period $t + i$, conditional upon the information available at time t; and r is the (constant) real rate of interest at which the household can both borrow and lend. This specification assumes that the household is infinitely lived, that there is no difference between lending and borrowing rates, and that the term structure of interest rates is flat. Relaxing these assumptions complicates the analysis but does not alter any of the important conclusions of the model.

The important characteristic of this definition is that permanent income is constructed so as to be expected to remain constant over the planning horizon. In other words, if the information which becomes available in period $t + 1$ does not alter the expected value of income in any of the future periods, then the estimate of permanent income will not change. This implies immediately that the only factor that will cause permanent income to change will be new information about the expected future path of actual income. This point may be formally stated by solving equation (1) for the change in permanent income:

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This is a summary of a paper entitled "The Rational Expectations Approach to the Consumption Function—A Multi-Country Study," scheduled for publication in the *European Economic Review* in 1980.

[1] The revival of the analysis of permanent income begins with the work of Sargent, 1977, and Hall, 1978. The present exposition is based upon the discussion in Flavin (1978b) who points out an error in Sargent's derivation and demonstrates an essential equivalence between the theoretical models of Sargent and Hall.

$$(2) \qquad \Delta y_t^p = \frac{r}{1+r}\Delta A_t + \frac{r}{1+r} \sum_{i=0}^{\infty} [E_t\, y_{t+i} - E_{t-1}\, y_{t+i-1}](1+r)^{-i}.$$

The term inside the square brackets may be decomposed into the change in the expected value of income in period $t + i$, $E_t\, y_{t+i} - E_{t-1}\, y_{t+i}$, and the expected change in income conditional upon the information set of period $t - 1$, $E_{t-1}\, \Delta y_{t+i}$. Since $E_{t-1}\, \Delta y_t^p = 0$, equation (2) implies that

$$(3) \qquad \Delta A_t = - \sum_{i=0}^{\infty} E_{t-1}\, \Delta y_{t+i}\, (1+r)^{-i}.$$

The term on the right-hand side of this equation is the negative of the change in the stock of wealth that arises from the anticipated future changes in actual income. The equation states that this value will be equal to the change in the stock of assets from $t - 1$ to t. It is through this pattern of saving or dissaving that the household maintains a constant expected level of permanent income in the face of anticipated variation in the flow of actual income.

This does not mean, however, that the actual estimate of permanent income is constant or, for that matter, even stable. Substituting equation (3) into equation (2) yields the general expression for the change in permanent income,

$$(4) \qquad \Delta y_t^p = \frac{r}{1+r} \sum_{i=0}^{\infty} DE_t\, y_{t+i}\, (1+r)^{-i}.$$

In equation (4), the operator DE_t denotes the change in the expected value and it is defined by $DE_t\, y_{t+i} = E_t\, y_{t+i} - E_{t-1}\, y_{t+i}$. Equation (4) views the household as receiving new information in period t about the expected level of income in period $t + i$ and then adjusting its estimate of permanent income by the present discounted value of these changes in expected value. The equation also illustrates the fundamental feature of the RE-PIH model emphasized by Hall: since permanent income will change only in response to new information, the change in permanent income will be white noise. In other words, under rational expectations it should not be possible to predict the change in permanent income, and hence the induced change in consumption, on the basis of previously available information because this information already will have been discounted into the estimate of permanent income at the time that it becomes available. The idea that demand functions based upon the notion of permanent income are more stable than those based upon actual income is not, therefore, an implication of the theory.

In order to complete the theory, it is obviously necessary to describe the process through which households form their estimates of future income. Although a number of approaches to this issue are possible, the discussion here will be restricted to the assumption that the information set is restricted to the past history of the actual income series.[2] In addition, the time-series process generating actual income is assumed to be the infinite order, stationary, invertible moving-average process,

$$(5) \qquad \Delta y_t = \sum_{i=0}^{\infty} \psi_i\, u_{t-i}.$$

Equation (5) is a useful forecasting equation for the RE-PIH model because the new information is restricted to the current innovation, u_t, and because the update in the expected change in income in period $t + i$ is simply defined by $DE_t\, \Delta y_{t+i} = \psi_i\, u_t$. Because the level of income in $t + i$ can be written as $y_{t-1} + \sum_{j=0}^{i} \Delta y_{t+j}$, the change in the expected level of income in period $t + i$ is simply the sum of the updates in the expected changes from t to $t + i$:

$$(6) \qquad DE_t\, y_{t+i} = \sum_{j=0}^{i} \psi_j\, u_t.$$

Substituting this result back into the definition of permanent income in equation (4) yields the following expression relating the change in permanent income to the innovation in actual income:

$$(7) \qquad \Delta y_t^p = \alpha\, u_t.$$

The α coefficient, defined to be $\sum_{i=0}^{\infty} \psi_i\, (1+r)^{-i}$, may be interpreted as the present discounted value of the moving average coefficients. The size of α depends upon the extent of the serial correlation in the actual income series which, in turn, depends upon the structural characteristics of the macroeconomic system. In the Keynesian unemployment model, for exam-

[2] See, for example, the empirical sections of the papers by Barro, Bilson and Glassman, Hall, Flavin (1978a) and Sargent.

ple, where the changes in actual income in response to an innovation in aggregate demand are assumed to be positively correlated through the multiplier mechanism, the α coefficient is likely to be greater than unity. There is no presumption, then, that the variance of permanent income will be less than the variance of actual income although, as an empirical matter, this is likely to be the case.

Equation (7) carries two empirically testable propositions. First, if consumption is proportional to permanent income, then consumption should respond only to unanticipated changes in actual income. Again, the reason for this result is that any anticipated change in actual income will already be discounted into permanent income and, hence, into consumption expenditures. Second, the marginal propensity to consume out of unanticipated income should be approximately equal to the α parameter estimated from the time-series model. If this condition is not met, then the household will violate its anticipated intertemporal budget constraint and consequently will not be able to maintain the current level of consumption expenditure.

There are a number of ways in which tests of the RE-PIH model can be run.[3] In the following, one set of tests based upon aggregate consumption data for three developed countries—the United States, the United Kingdom, and the Federal Republic of Germany is presented. For a number of reasons, these tests should be considered as illustrative. The most glaring weaknesses include the fact that the consumption measure includes the consumption of durable goods and that the forecasts of actual income are not based upon all readily available information.

Empirical Tests of the RE-PIH Model

The first step in the empirical analysis is to estimate the time-series process generating real per capita disposable income. In this analysis, disposable income is defined as gross national product less government expenditure rather than the more usual gross national product less taxes. The neo-Ricardian definition of disposable income was considered to be more consistent with the RE-PIH assumption that the household completely discounts anticipated future tax liabilities so that tax finance and deficit finance have symmetric effects on disposable income. Second, this measure of disposable income avoids problems associated with certain large tax rebates that induce spurious correlation in the conventional disposable income time series process.

The estimated models are presented in table 1. The theoretical model, with its infinite order, moving-average (MA) process, is implemented by truncating the MA process at lag 10. It is clear that this model "overfits" the sample data in each sample. Many of the estimated coefficients are not significantly different from zero. Each of the models do, however, exhibit a characteristic pattern of negative MA coefficients in the first four lags followed by positive coefficients at the longer lags. This implies that the typical reaction to an income innovation is for the initial shock to be followed by further income changes in the same direction before a reversal is felt.

In conjunction with equation (7), the estimates presented in table 1 can be used to estimate the α coefficient of the permanent income model. Since the α coefficient is also a function of the rate of interest, the estimates of the α parameter are given for a range of values of the real rate of interest, which is expressed in units of percent per quarter. Because the interest rates are quarterly real rates, the normal range would be from zero to 2%.

	Interest Rate (%)		
Country	0.0	2.0	4.0
Germany	0.1112	0.2706	0.4306
	(0.10)	(0.09)	(0.08)
United Kingdom	0.1422	0.2977	0.4240
	(0.08)	(0.07)	(0.06)
United States	0.1903	0.3814	0.5375
	(0.10)	(0.09)	(0.08)

The standard errors of the estimated coefficients are included in brackets beneath the estimates. It is interesting to note, in this regard, that the α parameters are estimated precisely despite the apparent imprecision of the estimates of the time-series models. The implication is that the long-run response to an innovation is quite stable despite the fact that the adjustment to the long-run state is not precisely estimated.

The estimates of the α parameter have the

[3] In Bilson, a number of other tests of this model are presented. Other approaches are contained in the references cited in footnote 2.

Table 1. Real Personal Disposable Income Per Capita Time-Series Analysis

Lag	Germany 1963:I–1978:IV	United Kingdom 1963:I–1978:IV	United States 1963:I–1978:IV
	ψ_i	ψ_i	ψ_i
1	−0.1044	0.1046	−0.1105
	(0.13)	(0.13)	(0.14)
2	−0.1322	−0.1727	−0.2452
	(0.13)	(0.13)	(0.13)
3	−0.1390	−0.0340	−0.3414*
	(0.13)	(0.09)	(0.11)
4	−0.0152	0.0091	−0.0539
	(0.13)	(0.08)	(0.11)
5	0.1921	−0.1338	0.2001
	(0.12)	(0.07)	(0.12)
6	0.1073	−0.2504*	0.1126
	(0.12)	(0.07)	(0.12)
7	0.4181*	0.0758	0.1312
	(0.12)	(0.09)	(0.12)
8	0.0161	0.7973*	0.4948*
	(0.13)	(0.08)	(0.11)
9	0.5382*	−0.0622	0.4098*
	(0.13)	(0.13)	(0.12)
10	0.0078	0.4399*	0.2178
	(0.14)	(0.13)	(0.13)
Δy	83.327*	2.9720*	30.637*
	(9.34)	(0.37)	(3.96)
Standard error	168.48	6.4183	57.431
R^2	0.267	0.440	0.379
F-statist. (10,52)	1.89	4.090	3.17
$Q(12)$	1.3	3.6	1.8
$Q(24)$	10.1	11.7	10.0
$Q(36)$	20.5	16.5	20.7

Note: Standard errors are in parentheses beneath the coefficients. An asterisk indicates that the estimated coefficient is significantly different from zero at the 5% significance level.

following interpretation: at a zero real rate of interest, a one dollar increase in income of \$1.00 should be associated with a 10¢ to 20¢ increase in permanent income. Because the income reversal takes place in the future, higher interest rates discount the future decline in income relative to the current increase and hence the α parameter increases with the rate of interest. In addition, because the future income is more uncertain than the current income, higher discount rates also are associated with more precise estimates of the α coefficients.

To test the RE-PIH model, the equation

$$(8)\quad \Delta c_t = \beta_0 + \beta_1\, uy_t + \beta_2\,[\Delta y_t - uy_t] + \beta_3\,\Delta w_t + \beta_4\,\Delta s_t + v_t$$

is estimated. In this equation, Δc_t is the change in per capita consumption expenditure, uy_t is the innovation in real disposable income per capita, Δw_t is the change in the real wage, and Δs_t is the change in the real stock price index. The real wage is included as a relative price variable. Higher real wages are expected to increase consumption expenditure by inducing the household to increase its supply of labor to the market and to substitute toward market goods in its household production function. Alternatively, if the wage index is considered as a measure of "expected prices," the real wage may represent the relevant relative price of current consumption goods relative to future consumption goods. The real stock price index is included in the consumption function as a measure of wealth. Hall demonstrates that this variable is related significantly to consumption expenditure in the United States, and Barro includes real corporate profits as an alternative proxy variable. It is necessary to include these variables in the regression equation to prevent a spurious significant coefficient on the anticipated income term because of the cyclical movement in real wages.

The main interest in the regression is, however, in the first two terms. Under the RE-PIH hypothesis, the coefficient on the unanticipated income term, uy_t, should not be sig-

nificantly different from the estimate of α from the time-series process. Also, the coefficient on anticipated income, $\Delta y_t - uy_t$, should not be significantly different from zero, because anticipated changes in income should not influence permanent income in the current period. The results of the estimation are presented below:

GERMANY: 1964:I–1978:IV

$$\Delta c_t = \underset{(10.64)}{22.8907} + \underset{(0.07)}{0.1883}\, uy_t + \underset{(0.07)}{0.0779}\,(\Delta y_t - uy_t) + \underset{(656.4)}{3074.4}\, \Delta w_t + \underset{(679.0)}{1747.8}\, \Delta w_{t-1} + \underset{(109.3)}{119.21}\, \Delta s_t + v_t$$

$R^2 - 0.43$ $F(5,53) = 7.965$ $D.W. = 1.90$
$S.E. = 65.66$ $RHO = -.295$

Autocorrelation Function of Residuals ($S.E. = .13$)

1 – 12 0.03 0.03 0.05 −0.06
0.06 −0.26 −0.11 −0.06
0.08 0.02 −0.09 0.03

UNITED KINGDOM: 1964:I–1978:IV

$$\Delta c_t = \underset{(0.35)}{0.4529} + \underset{(0.06)}{0.3604}\, uy_t + \underset{(0.06)}{0.0641}\,(\Delta y_t - uy_t) + \underset{(22.7)}{79.623}\, \Delta w_t + \underset{(2.21)}{4.3435}\, \Delta s_t + v_t$$

$R^2 = 0.55$ $F(4,54) = 16.46$ $D.W. = 2.03$
$S.E. = 2.78$ $RHO = -.197$

Autocorrelation Function of Residuals ($S.E. = .13$)

1 – 12 −0.02 −0.11 −0.09
−0.10 0.07 0.03 −0.06
0.08 −0.05 0.08 0.04 −0.21

UNITED STATES: 1964:I–1978:IV

$$\Delta c_t = \underset{(3.52)}{12.4255} + \underset{(0.06)}{0.2313}\, uy_t + \underset{(0.07)}{0.2582}\,(\Delta y_t - uy_t) + \underset{(448.0)}{2536.8}\, \Delta w_t + \underset{(41.24)}{90.6466}\, \Delta s_{t-1} + v_t$$

$R^2 = 0.65$ $F(4,54) = 25.24$ $D.W. = 2.16$
$S.E. = 23.90$ $RHO = -.217$

Autocorrelation Function of Residuals ($S.E. = .13$)

1 – 12 −0.08 −0.38 −0.07
0.05 −0.01 0.16 0.03 −0.17
−0.19 0.28 0.21 −0.21

In these results, the t-statistics are included in the parameters below the coefficient estimates. Before proceeding to the tests of the RE-PIH model, it is interesting to note that there is a strong real wage effect on consumption in each of the countries under study. In addition, either the current or first lag of the change in stock prices also appears to be significantly related to the change in consumption expenditure. These results may be taken to support the classical form of the consumption function relative to the Keynesian variant.

From the regression results, a new set of α coefficients may be obtained from marginal propensity to consume out of unanticipated income. Under the assumption that the distribution of the α coefficient is normal, the difference $(\alpha_1 - \alpha_2)$, where α_1 is the estimate from the time-series analysis and α_2 is the estimate from the regression model, will also be normally distributed. If the two estimates are independent, the variance of the difference is simply the sum of the variances of the two estimates. The compatibility of the two estimates may then be compared by constructing the standard normal variable $(\alpha_1 - \alpha_2)/(\alpha_1 - \alpha_2)$, where $(\cdot)$ is the sample standard deviation, and testing if this difference is significantly different from zero. The values of the standard normal variable are given below for a range of values of the real rate of interest:

Interest Rate	Germany	United Kingdom	United States
0.0	−0.57	−2.20	−0.34
2.0	0.79	−0.65	1.39
4.0	2.07	0.71	3.10

In general, these results are supportive of the RE-PIH model. In each case, the statistic is not significantly different from zero for interest rates in the range of zero to 2%. Only in the case of the United Kingdom is the real rate of interest that would be compatible with the hypothesis greater than 2% per quarter, and this result could be due to sampling variation.

The second implication of the model—that anticipated income changes will not influence consumption—is also strongly supported in the samples from Germany and the United Kingdom. In these cases, the coefficient on the anticipated income term is both small and not significantly different from zero. In the U.S. case, however, the data deals a rejection to the null hypothesis since the coefficient on anticipated income is relatively large and sig-

nificantly different from zero. In fact, in the U.S. case, the evidence suggests that the appropriate income measure is actual, rather than permanent, income.

Conclusion

The object of this paper is primarily methodological in the sense that it has attempted to point out the implications of the permanent income hypothesis for the estimation of aggregate demand functions rather than attempt to provide a set of "best" estimates of the aggregate consumption function. For this reason, the actual empirical results must be considered as tentative illustrations rather than as econometric evidence upon which definitive conclusions can be based. In particular, the evidence is weakened by the failure to develop a complete model for forecasting actual income and by the failure to distinguish between different types of income and different types of consumption goods. Despite these and other obvious weaknesses, the results are generally supportive of the approach and they suggest that the application of rational expectations methodology to the estimate of demand functions with permanent income may be a fruitful and exciting extension of current applied economics.

References

Barro, Robert J. "Permanent Income and Expected Future Income in a Time Series Study of Consumer Expenditure." Unpublished paper, University of Rochester, Apr. 1977.

Bilson, John F. O. "The Rational Expectations Approach to the Consumption Function—A Multi-Country Study." *Europ. Econ. Rev.*, in press.

Bilson, John F. O., and James E. Glassman. "A Consumption Function with Rational Forecasts of Permanent Income." Unpublished paper, University of Chicago, 1978.

Flavin, Marjorie. "The Adjustment of Consumption to Changing Expectations about Future Income." Unpublished paper, Massachusetts Institute of Technology, July 1978a.

———. "Comment on 'Rational Expectations, Econometric Exogeneity and Consumption,' by Thomas Sargent, *Journal of Political Economy*, August 1978." Unpublished paper, Massachusetts Institute of Technology, Nov. 1978b.

Hall, Robert E. "Stochastic Implications of the Life Cycle-Permanent Income Hypothesis: Theory and Evidence." *J. Polit. Econ.* 86(1978):971–88.

Muth, John F. "Rational Expectations and the Theory of Price Movements." *Econometrica* 29(1961):315–55.

Sargent, Thomas. "Rational Expectations, Econometric Exogeneity and Consumption." *J. Polit. Econ.* 86(1978):673–700.

Post-Keynesian Economics and Agriculture: Discussion

Bruce Gardner

These three papers are about as diverse as can be in a session on a particular topic. The topic, post-Keynesian economics and agriculture, is already broad because of uncertainty about exactly what post-Keynesian economics consists of. The session is even broader because one of the papers, Shaffer's, is somewhat tenuously related to post-Keynesian economics and another, Bilson's, does not have anything in particular to do with agriculture.

Work labelled as "post-Keynesian" seems to fall in two categories. One category continues into uncharted territory on lines of inquiry initiated, or believed to have been initiated, by Keynes. Although I have some trepidation about the political connotation of the term, this may be called left-wing post-Keynesianism. It is exemplified by Joan Robinson's writings. The Chichilnisky and Taylor paper seems to fall into this category. The second category constitutes to some extent a reaction against Keynesian ideas. It may be called right-wing post-Keynesianism. It is exemplified by the rational expectations approach to macroeconomics. Bilson's paper is interesting in that it falls into the latter category, yet provides new ammunition for certain Keynesian positions as against counter-Keynesian claims. This serves to illustrate the limited usefulness of the left-wing and right-wing labels.

The Chichilnisky and Taylor (C&T) paper is clearly Keynesian in that the income-expenditure relationship expressed in the simplest "Keynesian cross" plays a central role in the model. From this point, matters quickly become for me much less clear.

I have two main concerns that leave me unwilling to accept the models of the C&T paper as appropriate for either positive analysis or policy recommendation. First is a lack of a clear statement of the microfoundations of the model, and the dubious nature of the microfoundations as I understand them. Second is the lack of empirical support for the model.

On the first point, I would have been extremely grateful to have had a concise list of the assumptions made in each of the two models, a list of the endogenous and exogenous variables, classified as such, and mathematical statements of the basic behavioral equations and identities used. An example of my difficulties in these areas is the following statement from late in the paper: "Largely to avoid unilluminating mathematics, labor and capital are assumed to be freely shiftable between the sectors, and fixed coefficients for these inputs characterize technology." There is real economic content here, not just mathematical complications to be so casually swept away. I would like to have known if these or other assumptions also lie behind the earlier model of figure 1, or, if such assumptions are irrelevant to that model, why this is so. Generally, a mathematical statement of the model would almost surely be illuminating because it would necessarily lay out in detail which variables were assumed to be functions of which others, and which were exogenous, left out, or redundant.

Like most agricultural economists, I suppose, I am most comfortable with supply and demand as the basis for economic modeling of a sector of an economy. Consequently, the most natural multisector models are those based on aggregation of sectoral supply and demand equations, i.e., Walrasian general equilibrium models or the corresponding two-sector neoclassical general equilibrium model used, for example, in the Rybczynski paper that Chichilnisky and Taylor cite. What C&T must sell, in this view, is the notion that the supply-demand approach should be replaced by the Keynesian model for purposes of sectoral policy analysis, particularly for agricultural policy. To this end, it would have been illuminating, I think, to contrast the consequences of exogenous events such as import

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controls, decreased production of agricultural products, or a shift in demand for nonagricultural products in the Keynesian model compared to the consequences of analogous shifts in a neoclassical model. For example, in the case of import restraints, a neoclassical approach would involve considering the elasticity of domestic demand for and supply of agricultural products, and income effects and factor-market adjustment in the nonfarm sector. The Keynesian model involves the *ex ante* trade deficit and required savings in the agricultural sector, and the effects of agricultural prices on demand for nonagricultural products. Similarly, the effect of a production shortfall depends first and foremost on elasticities of demand in standard theory, and C&T's discussion in terms of savings and demand effects in nonagriculture seems to elevate second-order effects to primary roles. Can these different approaches be made to mesh? If not, is the implication that the behavioral parameters that we usually think central in analyzing the effects of, say, a tariff on sugar, really irrelevant?

In their final paragraph, C&T say: "The question is whether or not the models capture slices of likely economic response. Our view is that they do. . . ." This expression of opinion, unbuttressed by reference to any empirical work, is the entire justification offered by the authors in favor of adopting their models as tools for policy analysis. Much more is needed, to my mind, to argue for adoption as a policy tool a model in which the Keynesian cross applies to a single sector, nonagricultural prices and wages are exogenously fixed, and there is no supply function in its usual neoclassical sense for either agricultural or nonagricultural products.

Minor points: (*a*) in C&T's second model, the absence of land as a factor of production in A is striking. When land is included, the relative share of labor in agriculture is lower than in nonagriculture, contrary to C&T's treatment of nonagriculture as the capital-intensive sector. (*b*) The discussion of inflation seems quite ad hoc in that the model contains no financial sector, governmental activity, taxes, or money. Indeed, it is not clear that the general price level is determinate in this model—any level of the CPI would be consistent with equilibrium. (*c*) It is not clear why the models pertain to a "semi-industrialized" economy as opposed to a fully or nonindustrialized economy. The idea must be: The more plausible assumption for such an economy is that nonagricultural output is determined by demand, while its price is fixed. But why?

Turning to the Bilson paper, the only important weakness I can attribute to the author is his decision to present it at a session on agriculture. The idea that permanent income may in fact be a much less stable variable than one might at first suppose is an interesting one. The implication that an individual's consumption follows a random walk under rational expectations provides a potentially useful way to place consumption in the stochastic simulation models of growth of farm firms that one sees in the literature. The treatment of consumption expenditures in almost all of these models is so inadequate as to be scientifically scandalous. Bilson's approach might well provide a vehicle by which these sinners may reform.

On the Shaffer paper, my main complaint is that despite its subtitle, the progress toward a conceptual framework is too slight. We have concepts in plenty but too little framework. The E-B-P (environment, behavior, performance) sequence does not provide enough structure to illuminate one's thought processes about the political economy, at least not mine.

My ability to understand what the paper is driving at was hindered at times by a lack of precision in definition of terms. The "environmental situation" is a basic concept in the paper, as is "opportunity set," but neither the distinction between them nor the content of either was made clear enough. Early in his paper, Shaffer says: "Participants in a political economy exist in an environment situation which is their opportunity set." Soon thereafter we read: "The environment can be thought of conceptually as overlapping opportunity sets." And then "his opportunity set is governed by the external environment and the internal structure of the organization and his positions."

Similarly, the concept of "articulating" preferences is introduced as follows: "Individuals articulate preferences, that is, seek their goals. . . ." But later, in discussing preferences for the option of having a local store available, articulation is made parallel to expressing preferences. And then, in discussing equity, the problem of articulating preferences is explained in terms of "policies to reflect preferences for justice." Both these ideas are combined in the definition: "Preference articulation refers to the processes by which prefer-

ences are expressed and taken into account." Finally, in the section on vertical coordination, articulation appears to consist of coordinating preferences. In the end, it is quite unclear whether articulating preferences means to express them, to have policies reflect them, to coordinate them, to seek their satisfaction, or some combination of these activities.

This looseness of thought defeats the attempt to make progress toward a conceptual framework. In addition, the ambiguities create difficulty in assessing specific assertions made in the course of Shaffer's general tendency to diagnose the source of various problems as the lack of an appropriate institution. He says: "Problems exist in articulating preferences for the option to have adequate food available at a future date. . . . It is not possible to articulate preferences for equity through the market." One's reaction to these claims depends on what the term "articulate" is taken to mean.

I would like to introduce some final general remarks about this session with Shaffer's statement that his paper's "connection with post-Keynesian economics is that of a common belief that existing paradigms are inadequate. . . ." This view, and Shaffer's subsequent discussion, seem to me to illustrate both a desirable and an undesirable aspect of this kind of writing. The desirable aspect is the intellectual risks taken, encouraging us to entertain new ideas and to question old ones. The undesirable aspect results from what Johnson calls "the tempting thought that revolutionary new truths about the economic system can be intuited by rejecting existing ideas about it" (1971, p.3). The result is that one too often finds authors writing under the post-Keynesian label who are not interested in providing organized facts, analysis, or research results, but instead are telling us what we ought to be doing in place of our current research; in short, they are preaching. Our authors today are to be commended for avoiding this approach, for the most part. (As a discussant, it is of course acceptable for me to preach as much as I wish.)

To sum up: in my search in these papers for ideas for improving my understanding of the economics of agriculture or food policy analysis, I came up empty-handed. Shaffer is too vague, Chichilnisky and Taylor too empirically unsubstantiated, and Bilson too unrelated to agriculture. Nonetheless, some of the ideas put forth could well lead, in future development, to improved understanding and analysis.

Reference

Johnson, Harry. "Reflections on Current Trends in Economics." *Aust. Econ. Pap.* June 1971, pp. 1–11.

Post-Keynesian Economics and Agriculture: Discussion

G. Edward Schuh

The three papers we have heard are most challenging and interesting. Since they are quite different in their perspectives, they do not lend themselves to an integrated discussion. Hence, I will discuss each of them separately.

Shaffer's paper, although focused on an important topic, is both frustrating and disappointing. The title of his paper suggests that he will take initial steps toward a conceptual framework that presumably will do a better job of describing the food system than we have had in the past, and which will give us a sounder and more comprehensive basis for evaluating the performance of the food system. In point of fact, however, there is little theory in the paper, or little which in my judgment takes us very far in terms of having a more realistic or more general description of the food system.

Shaffer's paper is perhaps too ambitious for the time and *Journal* constraints of this session. As a consequence, certain sections read like a series of random ideas with no theme. In fact, most readers will probably find it difficult to keep the theme of the paper in mind as they read it. The paper also has a sufficient number of statements so elliptical in nature as to be of little analytical value as to suggest that it was squeezed down from a larger paper.

But let me be more positive. As I understand this paper, and as I understand North Central Regional Project 117, the objective is to understand important dimensions of the U.S. food system that have been neglected in the past. Participants in that project presumably believe that neoclassical economic theory is too narrow a framework to understand that system. Hence, they have attempted to broaden the analytical framework.

That is an admirable goal, and certainly is to be encouraged. Neoclassical economics is obviously not the only road to the truth. Moreover, our job as social scientists will not be done until we understand what goes on in households as well as in firms, until we understand why governments do what they do, and until we understand the behavior of organizations such as labor unions and other such entities that do not fit neatly into the categories of firms, households, and government.

Despite my respect for this goal, I have some serious reservations about the routes that are currently being taken to attain it. Moreover, I fear that we are engaged in much too much ad hoc-ery, and are investing all too little in developing a solid analytical or conceptual work. In this context I would like to make four points:

(*a*) First, to understand the behavior of some entities, it would be useful to start with simple behavioral axioms, work through the implications of these in terms of predicted behavior, and then test these predictions with data. Although many of us will challenge the postulates of conventional theory, few of us do what sound scientific procedure suggests we should do—formulate, examine, and test alternative hypotheses about behavior and performance. Perhaps the best example of this is with the government sector. All too often we either assume government behavior to be exogenous, or we assume that it is irrational. Having been part of the government sector myself, it seems clear to me that it is very responsive to price and other economic stimuli. Similarly, having been a part of government, I obviously believe it is sheer foolishness to assume that governments are irrational.

(*b*) Second, we should make better use of well-accepted concepts we now have available to us, such as concepts of market failure, externalities, free riders, and public goods. These concepts can help us to understand a great deal of the imperfections we see in the market place. Unfortunately, we have a tendency to give lip service to these concepts, but we seldom go much beyond that.

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(*c*) I sadly fear that we do not draw sufficiently on the other disciplines of the social sciences in extending our economic models. For example, political science has a great deal that can be of use in developing a theory of political economy. Similarly, many of the attempts to move away from the narrow confines of neoclassical theory take us onto ground already well-trod by the sociologists. Parson's "A Theory of Action" was an attempt at developing a more general theory of behavior than that provided by neoclassical economics. Have we really tried to take advantage of that theory? Or of other developments in sociology?

My concern is that there is little reflection of these other bodies of theory in Shaffer's paper, or in the other work of NC 117, for that matter. In fact, the membership of NC 117 is made up entirely of agricultural economists. It is this failure to draw systematically on these other disciplines that gives much of the work in this area its ad hoc character.

(*d*) Finally, we could make much greater use even of recent extensions of neoclassical theory. Again, there has been little attempt in agricultural marketing to draw on the new household economics to explain household behavior, as formulated by either Becker or Lancaster. Yet both of those bodies of theory would appear to have a great deal to offer in understanding phenomena that NC 117 is designed to understand.

To conclude, let me emphasize once again the importance of work in this area. To make much progress in filling the gaps in our knowledge, however, it seems clear to me that we need to make greater use of the other social science disciplines. If we were to make that effort, we might make an important step in reintegrating the social sciences into a more unified whole. That, too, has to be one of our goals.

The paper by Chichilnisky and Taylor deals with an important and until now relatively neglected set of issues—the connections between agriculture and the rest of the economy and the constraints these connections imply for economic policy. Their paper gives us a formal model by which we can interpret and analyze the rather large body of structuralist literature. Such formalization forces us to make our assumptions rather explicit, and facilitates the testing of that theory.

I would like to make six comments on this paper:

(*a*) The supply side of their model is deficient. The analysis is very much demand motivated, and goes into some detail on that side. The authors compare their results to those of the structuralist school in Latin America. One of the reasons for that similarity is that they are similar to the structuralists in their neglect of the supply side.

(*b*) In the first part of their paper the authors assume that food and most raw material demands are price inelastic. That implies that they are dealing with a closed-economy model. For some purposes that is useful. But for many countries one has to be concerned about the realism of this assumption. More important, in later parts of the paper the closed-economy assumption is relaxed, but it is not clear that the assumption about price elasticity has been changed.

(*c*) This model leads to what the authors consider to be a structuralist model of inflation. I question whether this model is adequate to imply anything about inflation. If it is, I would like to have this shown more carefully. My impression is that the model does not have enough equations to explain the price level. It is a model which can explain shifts in the terms of trade, but is it not sufficient to explain the price level.

(*d*) In the latter part of the paper, it is assumed that agriculture is the labor-intensive sector of the economy. That, of course, was the naive view for some time. We now have ample evidence of the capital intensity of agriculture, even in fairly primitive societies. It would be useful to work the analysis through with the opposite assumption. If the authors were to do this, while giving more attention to the demand implications of an open economy, some of their "puzzles" might well disappear. More specifically, the absorptive capacity of the agricultural sector might not be so limiting, and the responses to standard policy ploys might not be so perverse.

(*e*) In expanding the supply side of the model, I would encourage the authors to take account of what we are learning about agricultural development in terms of human capital and induced technical change. By this means we will be able to avoid going down the road of the naive growth models, models that became so abstract as to become sterile.

(*f*) Finally, the failure of the authors to tie their analysis to other papers in the field is rather disappointing. For example, they might benefit from a perusal of Flander's paper some

ten years ago, "Agriculture versus Industry in Development Policy: The Planner's Dilemma Reexamined."

Bilson's paper is different from the other two in that it reports on a rather straightforward econometric estimation of the parameters for the consumption function, using the rational expectations approach. I found it to be an insightful and rewarding paper.

An important contribution of this paper is the contrast it draws with the more straightforward permanent income approach to the specification of the consumption function. Unfortunately, the empirical tests of the model lead to ambiguous conclusions. Therefore, one is left with some rather deft econometric results, but with the state of our knowledge not having been advanced very far.

In discussing this paper, I would like first to make a comment, and then to ask a question. Hopefully, the question will lead to more general discussion of some of the implications of the rational expectations model.

My comment has to do with a possible reason for the rather anomalous statistical results. It would seem that it is rather naive to restrict K to be zero so that all of the information needed to forecast future income is assumed to be contained in the past history of the series. In fact, I fail to see how this procedure is greatly different than the distributed lag specification of the conventional consumption function, and I fail to see how one has done a great deal more than to test a particular specification of a distributed lag model. Moreover, why would not consumers be using a full-fledged economic model to make their forecasts of future income? And why would not this expectation model need to be fully specified so that we can take better advantage of what we already know about the economy?

My second comment is a question. Assuming that the world is rational expectationist, what does that imply for policy makers? If a policy maker is attempting to define a reserve policy for agriculture, for example, or to set target prices for agricultural commodities, how does he do it differently, or what difference does it make, if rational expectations are an appropriate approach to the world? I hope we can focus on this issue in the discussion.

Finally, I would like to challenge my agricultural economics colleagues to begin to test this new theory in their attempts to understand the agricultural sector. At one time agricultural economists were on the cutting edge in adopting alternative theoretical models and in adopting new quantitative tools. But to date we have virtually ignored the permanent income hypothesis. Let us hope we do not do the same thing with rational expectations. I suspect that this perspective has a great deal to offer in terms of improving our forecasts and in terms of understanding some of the cyclical behavior that characterizes the agricultural sector.

References

Becker, Gary S. "A Theory of the Allocation of Time." *Econ. J.* 75(1965):493–517.

Flanders, M. June. "Agriculture versus Industry in Development Policy: The Planner's Dilemma Reexamined." *J. Develop. Stud.* 5(1969):171–89.

Lancaster, K. "A New Approach to Consumer Theory." *J. Polit. Econ.* 74(1966):132–57.

Parsons, Talcott. *The Structure of Social Action.* Glencoe, Ill.: Free Park Press, 1949.

Agricultural Development: The Key Link in China's Four Modernizations Program

Robert F. Dernberger

Mao Tse-tung, the source of legitimacy for the radical leaders of the left-wing of the Chinese Communist Party, died in September of 1976. The radical left-wing leaders were arrested and removed from their positions of power within the month following Mao's death and a new, post-Mao leadership coalition under the control of the right wing slowly emerged during the course of 1977. Thus, in early 1978, Chairman Hua Kuo-feng's "Report on the Work of The Government," delivered to the National People's Congress, announced that the solution of China's economic problems would now take precedence over the ideological objectives of Mao's social and political revolution (Hua, 1978). To solve those problems, the National People's Congress adopted the Ten-Year Plan (1976–1985) for the Development of the National Economy, which Hua had summarized in his report. Utilizing themes originally put forth by Chou En-lai in the early 1970s, this Ten-Year Plan was to be the first stage in achieving the modernization of China's agriculture, industry, defense, and science and technology—the four modernizations—by the end of the twentieth century.

Ever since Hua's speech which announced the plan for achieving the Four Modernizations, Chinese leaders and press reports have emphasized continuously that "agriculture is the foundation of the national economy," and that "the development of agriculture at a high speed is the most important guarantee of success in modernization" (FBIS, 25 Oct. 1979). Furthermore, in the post-Mao spirit of respect for the facts, it is admitted that "China has difficulties in feeding the urban population and in ensuring a rational development of industries using farm products as raw materials" (FBIS, 6 Mar. 1979). According to a *Renmin Ribao* (6 Mar. 1979) editorial, "modernization will quite simply be out of the question if this state of affairs continues." Few Western specialists on China's economy, and I am sure none at this panel, would disagree with the argument that the modernization of China's agriculture, while not a sufficient, is a necessary condition for the modernization of China's economy.

The magnitude of China's agricultural development problem, the extent to which the Chinese have solved the agricultural problem over the past three decades, and the probability of their solving the agricultural problem in the near future, however, are topics of major disagreement among Western specialists. I have presented my position in this debate on more than one occasion (Dernberger). Inasmuch as Tang is presenting a paper on the trends in Chinese agricultural production in 1952–78 at this panel, while Lardy is a discussant, I gratefully yield to these two knowledgeable and capable specialists for their evaluations of the empirical record of China's agricultural development experience in the past. In this paper, I will devote my attention to what I consider an even more crucial determinant of China's success in achieving the modernization of China's agriculture in the future: the package of policies the new, post-Mao leadership has adopted to achieve the modernization of China's agriculture.

These policies, of course, were adopted by the new, post-Mao leadership on the basis of their own understanding of the empirical record of agricultural development over the past three decades, especially that of the more recent past. Western specialists who estimate and interpret this past record more favorably can claim the new, post-Mao leadership is motivated by the need to present the policies of their predecessors as failures; those whose estimates and interpretations provide us with a more pessimistic picture can argue the Chinese mean what they say when they claim

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to be seeking "truth from facts." Whatever their motives, the Chinese evaluation of their past record of agricultural development that has been made available to Western specialists over the past two years depicts the emergence, especially over the past decade, of an ever worsening situation.

For example, a study of grain production between 1965 and 1976 in 2,196 production teams in "various" provinces was reported at a conference sponsored by the Institute of Agricultural Economics of the Chinese Academy of Social Sciences at the end of 1978 (Guangming Ribao, 7 Dec. 1978). According to that report, yields had increased at an average annual rate of 2.8%, while costs had increased at an average annual rate of 4.0%. Furthermore, the value of a day's labor had declined from 0.70 yuan to 0.56 yuan over the same period. A major source of the increase in costs, as the estimates presented by Tang should indicate, is the rapid increase in the use of purchased inputs in the decade after 1965. Thus, inasmuch as output prices were not increased over the period between 1965 and the mid-1970s, it is not surprising to learn that the survey of grain production in 2,196 production teams in 1976 revealed that production costs (probably inclusive of labor costs), plus taxes, exceeded the state's purchase price by 10.6%. Or that a survey of cotton production in 302 production brigades in 1977 revealed production costs which exceeded the state's purchase price by 2% (FBIS, 26 Oct. 1979).

Although the reports of the State Statistical Bureau show that the total gross value of agricultural production (in current values) increased at an average annual rate of 6.2% between 1952 and 1978, grain output increased at an average annual rate of only 2.6% and the average per capita grain distribution was no greater in 1978 than two decades earlier in 1957.[1] Of more immediate importance, grain output did not grow between 1975 and 1978 and, therefore, grain availability per capita from domestic production was declining. Thus, when the new, post-Mao leadership came into power, these inherited developments in agricultural production not only were a serious threat to their ability to maintain the standard of living, they also threatened their ability to use agriculture products, a major source of export earnings in the past, for the purpose of increasing export earnings to pay for producer goods imports. It is not surprising, therefore, that a major concern of the new, post-Mao leadership over the past two years has been the introduction of new policies for achieving the modernization of China's agriculture.

China's New Agricultural Program

Our purpose in this brief paper is not to analyze the details of each of these new agricultural policies, nor to analyze the dynamics of their evolution as an integrated and complete program for the modernization of China's agriculture. In the course of 1978, the Chinese increasingly became aware that the mere arrest of the radical leaders and their followers would not eliminate China's fundamental economic problems and that, in light of these problems, the plan for 1985 was unrealistic. Thus, in Hua Kuo-feng's "Report on the Work of the Government" to the second session of the Fifth National People's Congress in the summer of 1979, he reported that a new five-year economic plan for 1981–85 would be drafted and ready for adoption at the next National People's Congress, and further, that the next three years, 1980–82, would be devoted to putting the Chinese economy back onto the path of sustained economic growth (Hua 1979).

Throughout 1979, a great many arguments have appeared in Chinese publications and many experiments are being tried out in a search for the proper set of institutional and policy changes that will put the Chinese economy back onto the path of sustained economic growth. According to Vice-Premier Ku Mu in October of 1979, "We have become convinced of the need to completely reform our economic institutions and economic policies from the top down to the lowest level, but how to reform them is a difficult problem and will take some time."[2] Any attempt to spell out China's new agricultural policy program at the present time, therefore, would be premature. On the other hand, the various agricultural policies that have been advocated and the institutional changes in agriculture that have been tried over the past two years do provide us with

[1] Average annual rates of growth were calculated by the author on basis of total values for 1978 and 1952. The 1978 totals are from FBIS, 3 July 1979; the 1952 totals are from State Statistical Bureau, 1960.

[2] Quote is from the author's notes from a briefing and interview given by Ku Mu for the delegation of American economists in Oct. 1979.

ample evidence of several basic themes of the new agricultural program currently evolving in China. The purpose of this paper is to present a summary of these basic themes and to assess their implications for the modernization of China's agriculture.

Perhaps the most surprising development has been the retention and open advocacy by the new leadership of many elements of the major program advocated and implemented by their predecessors: the Tachai or Advanced County Campaign. That campaign, especially its method of implementation during the first half of the 1970s, is now openly criticized. This is not true, however, for those components of the Advanced County Campaign which were designed to achieve a significant technological transformation of China's agricultural production. These included the innovation of new varieties and cropping patterns; the increase in irrigated area and use of chemical fertilizers; the mechanization of agriculture; extensive farmland reconstruction; the electrification of rural China; and the development of rural, small-scale industries for the production of cement, chemical fertilizer, iron and steel, agricultural machinery, and electric power. These policies were a major feature of Chinese agricultural development efforts in the first half of the 1970s.

On 5 October 1979, the Central Committee of the Chinese Communist Party issued a lengthy policy document on "Some Questions Concerning the Acceleration of Agricultural Development" that was adopted by the fourth plenary session of the Eleventh Central Committee of the Chinese Communist Party.[3] Of the twenty-five policies and measures for developing agriculture this document advocates, five repeat policies were being pursued in the early 1970s for the technological transformation of China's agriculture. Despite these similarities in policies per se, however, the new program for the modernization of China's agriculture represents a thorough and necessary "rationalization" of the technical ingredients of the Advanced County Campaign as it was carried out in the past.

As for the policy of developing new seeds and cropping patterns, the practice of every unit having an experimental plot is questioned as a waste of land; experimental plots can be more efficiently managed in communes which specialize in the production of new seeds. It is now admitted that inter-cropping and more multiple cropping have not raised annual yields everywhere, but have done so only under certain conditions. The practice of each unit producing a variety of crops to increase the degree of self-sufficiency or diversification is also found to be a source of inefficiency; specialization in those crops best suited to the climate and soils of the local unit are now argued as a better means for providing higher yields. For the purpose of facilitating the more scientific breeding of seeds and adoption of proper cropping practices and patterns, the Chinese have recently begun to survey and catalog soils.

In farmland reconstruction, the practice in the past of mobilizing farm labor for these projects is criticized for the extent to which it ignored the opportunity costs of labor, and examples are cited where yields in crop production and the income of peasants declined as a result. Some of the projects in the past also have been criticized for the poor design, poor results, or ineffectiveness in increasing yields, or their high costs in terms of scarce construction materials.

In irrigation, the rapid expansion of the irrigated area in the past is criticized on the basis of the low level of efficiency of the various irrigation projects, the extent to which they wasted resources, the extent to which their design capacity is not realized, and the extent to which mechanization is concentrated on a limited amount of irrigated land. In other words, a considerable increase in yields due to increased irrigation can be obtained by significantly increasing the efficiency of the existing irrigation system. As for new irrigation facilities, a major problem continues to be the North China Plain, and involves two major irrigation projects. Although somewhat dormant in the 1960s, considerable work has been done on the Yellow River project since 1949. The Chinese now admit, however, that the two most serious problems faced by the project have not yet been solved: silting and excessive alkalinity. Specialists are now being organized and a conference was held to propose solutions to these problems, solutions which are necessary if the potential of the Yellow River is to be harnessed for irrigation. The second major irrigation project is yet to be

[3] The full text of this document, as adopted by the fourth plenary session of the eleventh Chinese Communist Party Central Committee is reproduced in FBIS, 25 Oct. 1979. A preliminary draft of this document had been adopted by the third plenary session, Dec. 1978 and had been circulated, discussed, and modified in the intervening nine months.

tackled; tapping the better quality and more voluminous flow of water in the river system of Central China, especially the Yangtze River, and bringing that water to North China. Concern has been expressed, however, over the costs of such a project and the possible consequences of diverting water from the Yangtze to the North. The Chinese are now reconsidering the alternative routes and the costs and benefits of the project.

The problems uncovered in the attempts to electrify the rural areas are related to China's present economy-wide energy shortage. Agriculture undoubtedly will be given a high priority as a result of the readjustment of priorities in the current reevaluation of the national economic plan; and the electrification of the rural areas will remain as an objective of China's agricultural modernization program. Nonetheless, the inefficiency in the generation of electricity by the rural power stations and the efficiency of its present allocation and use have been questioned, especially in regard to the generation of electricity at much lower costs by means of large-scale, hydro-electric power stations and the use of electric power at much higher levels per unit of output in the rural, small-scale industries.

The mechanization of agricultural production gained great prominence in 1978, but the Chinese have had second thoughts about not only the feasibility, but the wisdom of mechanization. Articles in the Chinese press have argued that the objective of increasing yields calls for land-saving, or augmenting, technical change, while mechanization is a labor-saving, or augmenting, innovation. Thus, given the recognized inability to supply the machines required to meet the original targets for the mechanization of China's agriculture, mechanization should be emphasized in the less labor-abundant areas, i.e., on state farms in the Northeast. As for the production of agricultural machines, they should be produced in complete sets, and should be produced in factories which specialize in the production of their various components. To have agricultural machinery produced in short runs in factories spread throughout the countryside is simply too inefficient and costly.

Discussions in the Chinese press over the past year which concern the "rationalization" of industrial policy emphasize the extent to which many industrial plants are suffering financial losses, have a low productivity of labor, use excessively high levels of scarce resources per unit of output, and produce poor quality output. These criticisms are held to be especially true for many rural, small-scale, industrial plants. To correct for this problem, it is argued that unless they improve their profitability and reduce the input costs of their production, these inefficient plants should be closed down.

The expanded use of chemical fertilizer is the one element of the Advanced County Campaign's program for the technical transformation of China's agriculture that has not been criticized. Perhaps the reason for this is that much of the increase in yields achieved before 1975 can be attributed to the significant and rapid increase in the availability and use of chemical fertilizer. The rapid expansion of production and use of chemical fertilizer, therefore, continues to be a major objective of the new leadership.

As a whole, of course, the "rationalization" of the program for the technical transformation of China's agriculture in the Advanced County Campaign adds up to a significant change in policy introduced by the new leadership. Moreover, these changes, to the extent they are made effective in being implemented, should improve the probability of China's success in achieving agricultural modernization; not only by eliminating much that is wasteful or of limited use in increasing yields, but also by concentrating on those innovations which, in the historical experience of other countries, do achieve that objective.

An interest in the historical experiences of other countries relates to another major change in the new leadership's search for a solution to China's agricultural problems. In the past, the source of technical innovations and institutional and policy changes in agriculture was sought within the context of China's own experience. In order to pursue the objectives of self-reliance and participation by the masses, most communes throughout rural China experimented with low-level technical, institutional, and policy innovations. Those innovations the leadership selected as successful on the basis of their results alone, without a careful statistical analysis of cause and effect or costs and benefits. They were adopted as models to be copied in nationwide campaigns. The new, post-Mao leadership not only recognizes that innovations and policies that work in one region of China may not be appropriate to dissimilar environments found

throughout the rest of the country, but they also stress the need to learn the truth from facts by means of statistical analyses which ascertain if the results of an innovation are indeed what they are claimed to be and if they are worth the costs. Moreover, the experiences of those countries that have achieved successful agricultural modernization and high yields are being studied as a source of possible institutional and policy changes in China.

This search abroad for new knowledge as a basis for policy making and the greater emphasis placed on empirical testing for policies that are implemented should increase favorable prospects for China's future agricultural development. The new leadership's modification of the priority given agriculture in the state's allocation of investment funds should be of more direct benefit. Following the agricultural crisis at the end of the 1950s, the Central Committee of the Communist Party adopted a fundamental change in development priorities in August, 1962, recognizing that China's agricultural problems would not be overcome quickly or by means of institutional reorganization and greater labor inputs alone. Instead of agriculture receiving a relatively low priority compared to heavy and light industry as in the 1950s, henceforth agriculture was to be treated as the "foundation" of China's economy and economic development strategy. As a result of that decision, investments in agriculture and in industries producing inputs for agriculture were increased. Faced with those same agricultural problems almost two decades later, the Chinese now claim that the earlier shift in priorities was not enough. Thus, investment in agriculture was increased from 10.7% to 14% of the state's capital construction investment in the 1979 state budget, and it is claimed that the government will increase the agricultural share even more in the future (FBIS, 3 July 1979). In addition, in the process of the current readjustment of the production and investment plans for the industrial sector, those industries producing goods for use in the agricultural sector undoubtedly are to be given an even higher priority than in the past.

Economic, Social, and Political Problems

Compared with China's "rationalization" of changes in emphasis and priorities in its program for the technical transformation of its agriculture, the change in the incentive mechanism to achieve the desired results represents a rather sharp break with the past. In many campaigns, the cadres at the county and commune level were exhorted to mobilize the peasants to undertake the innovations described above. The whole thrust of the new agricultural policies, however, is an explicit rejection of this approach. Quite simply, the institutional and incentive structure being created in agriculture by the new, post-Mao leadership is for the purpose of motivating the individual peasant—or the low-level unit of production of which he is a member—to achieve high and stable yields because of the direct material benefits to himself. County and commune level cadres are to provide the necessary guidance and control, while the leaders of the Party will provide policy guidelines; but those leaders are relying heavily on the peasants themselves to get the job done.

In decision-making, production, and income distribution, the post-Mao leadership has put great emphasis on making real the promise of the new Constitution that the basic unit in agriculture will be the team. The commune and brigade level administrations remain important for administrative and large-scale investment and health, education, and welfare purposes, but the team has gained considerably greater freedom to determine how it will utilize the resources at its disposal for achieving the modernization of China's agriculture. To correct for problems that are said to have been common in the past, the ability of the team to elect its own team leader is to be restored and the resources of the team are not to be requisitioned by higher level authorities without "fair" compensation.

As for the distribution of income, the new, post-Mao leadership has devoted considerable attention to reinterpreting Marx to show that individual material incentives directly related to the quantity and quality of work done by the individual and income differences based on skill and effort differentials are consistent with the laws of economics in a socialist system. As in the past, the peasant's income from work done in the collective sector is based on the work points earned for that work, the value of the work point determined on the basis of the production of the collective unit as a whole. Nonetheless, work points are to be task specific and not awarded on the basis of time periods or on the political merits of the individual.

Although approximately 80% of the commune's farm land is still included within the state plan, production teams and individual households are free to determine their income earning activities in subsidiary activities.[4] To encourage their use of these opportunities to increase production of commodities that meet the needs of both the state sector and consumers, the leadership also has reinterpreted Marx to show that maximizing incomes is a desirable objective in a socialist economy and does not represent a restoration of capitalism. Furthermore, considerable encouragement is being given to specialization in these group and individual sideline activities. The new leadership also has tried to remove the ideological stigma attached to market activities, and rural and urban markets for these subsidiary products have grown rapidly over the past year. After its initial attempt to control transactions and prices in these markets, the government removed controls on most of the commodities traded on these markets because the administrative burden proved to be too great.

The most important agricultural products, of course, remain within the state plan and are sold to the state at fixed prices. Nonetheless, to provide greater material incentives for securing increased production and state procurements of these products, a significant price increase for state procurements of agricultural products was introduced in the summer of 1979. In addition, a much greater increase in price is paid for above-quota deliveries. The national average price increase for procurements of grain was 20%, 25% for oils and fats, 15% for cotton, and 26% for pigs. The average price increase for above-quota deliveries was 50% for grain and oils and fats and 30% for cotton (FBIS, 25 Oct. 1979). Finally, provincial and lower level authorities have been given the authority to reduce taxes to lighten any existing "excessive" or counter-productive tax burdens in the areas under their jurisdiction.

This summary statement of the producer-incentive policy changes introduced by the new, post-Mao leadership should be sufficient to indicate the extent to which the emphasis has been shifted from the county- and commune-level cadres to the peasants themselves as the instruments for achieving the modernization of China's agriculture. Equally important, these new policies also indicate the extent to which the new leadership believes that these price and income-earning incentives will achieve the desired results.

Future Problems and Prospects

To a Western trained economist, many of the above institutional and policy changes in China's agricultural program would appear to improve greatly the chances of achieving higher yields. Yet, it is not too difficult to think of problems the Chinese will encounter as changes in policy are implemented. Despite these new policies and even though the technical aspects of the advanced county campaign have been rationalized, the attempts to develop new seeds, increase irrigated area, increase the use of chemical fertilizer, and continue the electrification and mechanization of agricultural production will not be easy tasks to accomplish. These problems in the technical aspects of the modernization of China's agriculture, however, have been analyzed extensively in the published literature. Even given the serious nature of the inherited characteristics of China's fundamental agricultural problem, however, I believe that it is the nontechnical or economic, social, and political aspects of the new agricultural policies that will be the most important determinant of the long-run success of the current program to modernize China's agriculture.

For example, the new leadership claims the encouragement of low-level decision making and initiative, material incentives, and markets is consistent with the economic laws of socialism and do not necessarily represent a capitalist restoration. Nonetheless, Chinese press reports already have attacked those who have taken advantage of the new policies to decentralize the basic unit of production below the level of the production team; who have taken advantage of the encouragement to engage in subsidiary and income-earning activities, which threaten growth in the collective sector activities within the plan; and who have taken advantage of the encouragement to participate in market activities in order to engage in exploitation and speculation. Thus, in its search for greater efficiency and higher

[4] During their visit to China in Oct. 1979, the delegation of American economists was told by provincial and commune officials that 80% of the land in the commune was included in the state plan that was sent down to the communes. The targets in this plan included acreage to be planted in various crops, yields, and state procurements.

yields, the new leadership must continually be on guard that new policies do not erode the basic principles of socialism and eventually lead to a capitalist restoration in the countryside. In other words, the new leadership easily can find itself throwing the "clean baby out with the dirty bathwater."

Even assuming that the peasants' behavior and motives remain within the bounds of socialist values, however, the new policies will have consequences which will put severe strains on the objectives of China's version of socialism. After three decades of advocating greater equality in the regional or sectoral distribution of income, the existing inequalities in the standard of living within rural China and between the rural and urban areas are both obvious and considerable.[5] What is important is that the major thrust of the new agricultural policies—decentralization of decision making, productivity related material incentives, specialization, and a greater role for income-earning activities in the market—will tend to produce an even greater inequality of income. Lardy's study of the Chinese fiscal system shows how the central government's control of the budget process has been used in the past to redistribute some revenues from the richer to the poorer provinces so as to achieve a modest closing of the gap between relative levels of regional incomes. On the other hand, current experiments in the fiscal system, again for the purpose of creating material incentives to encourage local initiative, call for an increase in the share of locally collected revenue to be retained and spent at the local level.

As for the attempt to reallocate resources by means of physical allocations within the plan, current readjustment of the plan undoubtedly will give greater priority to agriculture (rural areas) and less to industry (urban areas). Yet, the material incentive mechanisms being implemented in both the rural and urban sectors and the increase in the role of markets for the provision of commodities to convert these money incomes into real consumption presents a challenge to the planners by reducing, to some extent at least, their control over the sectoral and regional allocation of resources. Thus, a more equitable distribution of income could well be one of the victims of "putting economics in command" for solving China's agricultural problem.

Even when the new incentive system did lead to a significant adjustment in the urban-rural inequalities by means of a significant increase in the prices paid for agricultural products delivered to the state, urban industrial workers were promised this price increase would not be passed on to consumers. However, because of losses suffered from buying agricultural products at prices above the retail price, the state raised retail prices. Yet, the decline in real income for the urban industrial worker would not only create considerable urban discontent, but also would threaten the hoped for increases in productivity from the wage increases that had been granted to industrial workers. In the end, the industrial worker will receive both his wage increases and a 60 yuan subsidy a year to offset the increase in retail prices for agricultural products. However, the average peasant, who earns an annual income of less than 100 yuan in many provinces of China, will receive an annual increase in income of approximately 8 yuan because of the increase in the price paid by the state for agricultural products. This explains why, during my recent visit to China, an agricultural official in Shensi answered my question as to what single change in agricultural policy was needed most for securing an increase in agricultural production by immediately replying, "another increase in purchase prices."

Although the widening of the gap between the rural and urban standards of living represents a direct rejection of a principal theme of Maoism, I believe the growing regional inequalities within the rural sector itself as a result of the new agricultural policies may present the Chinese leadership with an even greater problem. In some areas of rural China the peasants' standard of living is relatively high, even higher than that of an average industrial worker, while in many areas the peasants are poor. Mao, of course, was not the champion of all the Chinese peasants. Rather, his appeal was to China's poor and the agricultural policies he advocated were designed to improve their relative standard of living. This,

[5] For example, the delegation of American economists (Oct. 1979) was told that per worker (industry) annual income in Shanghai Municipality in 1978 was 780 yuan as against a distributed income of 270 yuan per capita in the communes. The same ratio was reported to be 693 to 68.3 yuan in Shensi Province and 600 to 94 yuan for Kiangsu Province. When the comparison is made more valid by converting urban workers' average incomes into their urban per capita equivalent, as was done by the authorities in Shensi Province, the comparison of worker and peasant consumption on a per capita basis in 1978 yields a ratio of 389 to 124.8 yuan. Finally, the ratio of the average per capita peasant income in the richest compared to the poorest county in Kiangsu Province in 1978 (the province with the highest gross value of agricultural output of any province in China in 1978) is 220 to 50–60 yuan.

I believe, was the crux of the "two-line struggle" of the past three decades; to benefit the poor or to benefit the most productive. In short, I believe the policies of the new, post-Mao leadership for the modernization of China's agriculture, which obviously benefit the most productive, are seriously challenging the objectives of Mao's socialist revolution. That challenge, I believe, is the greatest problem faced by the current campaign for the modernization of China's agriculture.

References

Dernberger, Robert F. "The Program for Agricultural Transformation in Mainland China." *Issues and Studies* Oct. 1978, pp. 59–97.

Foreign Broadcast Information Service. *Daily Report: People's Republic of China;* "CCP Central Committee's Decision on Agricultural Development," vol. 1, no. 208, supplement 032, 25 Oct. 1979.

"Further Report on Farm Price Increases," vol. 1, no. 209, 26 Oct. 1979.

"Purchase Prices for Farm Produce Raised," vol. 1, no. 208, 25 Oct. 1979.

"Renmin Ribao on Agriculture As Foundation of Economy," vol. 1, no. 045, 6 Mar. 1979.

Zhang Jingfu. "Report on the Final State Accounts of 1978 and the Draft Budget for 1979," vol. 1, no. 129, 3 July 1979.

Hua, Kuo-feng. "Report on the Work of The Government." *Beijing Review,* no. 27(1979), pp. 5–31.

———. "Unite and Strive to Build a Modern Powerful Socialist Country!" *Peking Review,* no. 10(1978), pp. 7–40.

Lardy, Nicholas R. *Economic Growth and Distribution in China.* Cambridge: Cambridge University Press, 1978.

State Statistical Bureau, People's Republic of China. *Ten Great Years, Statistics of The Economic and Cultural Achievements of The People's Republic of China.* Peking: Foreign Languages Press, 1960.

Trend, Policy Cycle, and Weather Disturbance in Chinese Agriculture, 1952–1978

Anthony M. Tang

Utilizing the estimated input-output time series for 1952–1978 developed in a larger study on the agriculture of the People's Republic of China, I attempt in the present paper (*a*) to quantify and analyze the secular behavior of total factor productivity of the sector; (*b*) to test and analyze the changing impact of weather on productivity in light of such developments as socialist reorganization of the countryside, massive water control, and introduction of new biological, chemical, and mechanical inputs within the context of Peking's successful "weather-proofing" claims; and (*c*) to isolate and attempt a crude measure of the cyclical swings in productivity attributable to policy or political cycles in the PRC. The total factor productivity index (*TFPI*) is residually calculated from an aggregate production function whose coefficients are assigned values from the estimated base-period (1952–57), relative factor income shares. (Aggregation is arithmetic on both the output and input sides.) The method is conventional enough and raises a number of familiar issues. Following Solow (p. 312) whose seminal work popularized the methodology, we make no attempt "to justify what follows by calling on fancy theorems on aggregation and index numbers. Either this kind of aggregate economics appeals or it doesn't." *TFPI* is obtained by dividing the gross value of agricultural output (*GVAO*) index by the aggregate input index.

The Chinese Development Strategy

In order to analyze Chinese agricultural performance in perspective, it is necessary to present first the country's development strategy and to spell out how agriculture is supposed to relate itself to the design. In the PRC, the Chinese Communist Party regards itself as the supreme repository of truths. The values and goals of its leadership generally displace those of the people. In a capsule form, these values are aptly summarized in a metaphor attributed to A. Bergson: To the party leadership, bread is an intermediate product; steel is the final good. Bergson's reference was to the Stalinist strategy of economic development—a strategy embraced by Peking's leaders as they assumed power in 1949. A concrete expression of the embedded values can be found in the oft-repeated aspirations of the Chinese leaders, present and past, of turning the PRC into "a modern, front-ranking power" (a superpower, if you will) by no later than the end of the present century.

The power-oriented value and goal imperatives, together with the clear sense of urgency attached to their attainment, dictated a development strategy best described as the "maximum-speed selective growth under austerity" and required a "command economic system" for implementation. While selectivity is associated with the modern heavy industrial sector, whose absolute size is the preponderant determinant of national power on contemporary world scenes, the command system es-

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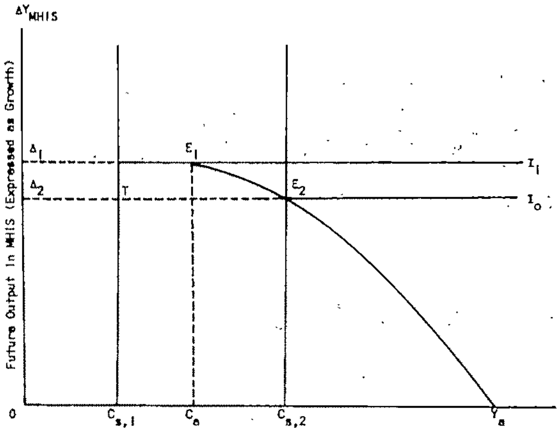
In the interest of space, the input-output time series are not presented in this paper. They are available to interested readers upon written request to the author. These estimates are, in turn, supported by some fifteen tables with explanatory notes and source references covering some forty pages. The detailed notes are designed to enable readers to retrace and recalculate every single entry in the tables. For such information, the readers are referred to the author's forthcoming monographic study to be published by the Center for Chinese Studies of the University of Michigan.

chews markets and prices in important ways, preferring to allocate critical economic resources administratively (i.e., the hard way).

The "bread-steel" metaphor makes it clear that the role of agriculture is to support priority (selective) industrialization with (extracted) savings articulated by real resource transfers in the form of food (the principal wage good), labor, raw materials, and exportable farm products. Recent statements from Peking remind us of the critical dependence of China's industrialization on agriculture. A special feature article in *Beijing Review* pointed out that agriculture contributes about 85% of the people's means of subsistence, 70% of the raw materials needed by light industry, 40% of materials needs of all industry, and "a considerably large part of our financial revenue" (Shi, p. 15). Where agriculture failed to meet the full resource transfers required by the priority industrial sector for maximum growth, the agricultural sector became the bottleneck acting as a drag on industrialization. In such a case, agriculture, though hierarchically inferior, becomes—in a planning and operational context—indistinguishable from industry. To develop agriculture is to develop industry. On the other hand, the effective bottleneck may lie outside agriculture with limitations in the foreign trade sector, the productive capacity of the capital goods sector, or the absorptive capacity of priority industry.



Note: The term "net" refers to output available for agriculture's own consumption and extracted savings by the state, after first meeting current resource requirements and wage good requirements for current production in *MHIS*. Current resource requirements include those covering depreciation for steady-state operation in *MHIS*. For simplicity, it is assumed implicitly that there is balanced trade via some state-stipulated set of terms of trade between agriculture and industry in current terms. Thus, extracted savings by the state bear on $\Delta MHIS$.

Figure 1. Maximum-speed selective growth model

By adapting elements from the Fisherian optimum saving and growth model, the Lewis-Ranis-Fei two-sector model, and the Chenery-Strout-MicKinnon-type constraint growth model, we offer in figure 1 a graphic representation incorporating all the salient features of the Chinese development strategy. The sectoring is between agriculture (the dominant branch of the economy where saving and resource mobilization for investment in industry must impinge) and the modern heavy industrial sector (*MHIS*) whose growth lends substance to the power-oriented development strategy. The horizontal indifference curves of the planner (who acts for the political leaders) follow directly from the "bread-steel" preference symbolism. Current consumption enters our model as a constraint set by some floor, subsistence standard (as at $C_{s,1}$ or $C_{s,2}$). This floor may be relaxed without altering our analysis to deal with the concept of an optimum wage and consumption in a maximum-speed growth context of Chiang and Fei in which the effort-productivity implications of the wage-consumption policy in a command economy are considered. (This is to say, location of C_s affects positively Y_a.) The intertemporal transformation curve (Y_aT) links up present agricultural resource transfers with future output growth in the priority *MHIS* sector.

The planner's object is to maximize his utility intertemporally within the planning horizon. (Beyond that horizon, after China achieves the power status it seeks, consumption enters the planner's social welfare function.) Given a present agricultural output OY_a (as defined in the note to fig. 1) and curve Y_aT for transformation, if $C_{s,1}$ is the floor for agriculture's own consumption of its output, the planner's optimum is at E_1, yielding Δ_1 for *MHIS* growth in the future period, actual consumption of OC_a (with ample margin over the set floor), and savings extracted from agriculture for investment in *MHIS* equal to Y_aC_a. Here, the binding constraint on industrialization is outside agriculture, and for the time being the state can neglect agriculture and concentrate investment on *MHIS* exclusively. In passing, we note that this was the case with Stalinist Russia in the 1930s (Tang 1968).

Placing the consumption constraint at $C_{s,2}$ (as with a larger agricultural population but about the same output as before), the planner now finds the effective bottleneck to his industrialization drive inside agriculture. His realizable maximum growth in *MHIS* is Δ_2. Own consumption for agriculture is held to the floor level at $C_{s,2}$. And forced savings, $Y_aC_{s,2}$, represents the maximum extraction. With agriculture as the bottleneck, the planner attempts to develop the sector by first emphasizing mobilization of indigenous resources of low or no opportunity cost to industry, exploiting traditional production possibilities and eventually exhausting them after increasingly severe diminishing returns. The development program takes on complexities not present earlier. All branches of the economy are now interdependent and compete for the planner's attention.[1] Basically conflicting dual policy requirements (output growth and maximum extraction) are imposed on agriculture. Bureaucracy and command structure grow accordingly. Even more so than before, direct quantitative controls are preferred as in rationing basic consumer goods (a Chinese practice since 1955).

In an attempt to deal with these problems, or "contradictions" in Marxian lexicon, efforts are made to find nonmaterial substitutes for incentive in order to raise output without incurring increased consumption (viewed as a cost by the planner). Inasmuch as China's industrialization has been agriculture-constrained as is clear from earlier empirical testing (Tang, 1968) and from Peking's recent own reckoning,[2] the country's preoccupation, especially under Mao, with "radical experiment"—a predilection as we shall argue later responsible for Peking's policy cycles—is quite understandable. So was Mao's singular concern with the problems of government and party bureaucracies, as symbolized by his concept of "permanent revolution" to keep the governing apparatus "renewed." At the opposite end from radical courses of action, Peking has shown a willingness to compromise high principles of socialism and nationalism. In the singular case of Hong Kong and Macao (where Peking virtually insisted that Britain and Portugal retain the territories as colonies) the bending of these principles is severe indeed. The overriding importance attached by Peking to its $2 billion-plus net annual foreign exchange earnings through trade, remittances, and its banking and commercial operations in the two Western colonies, attests at once to the preeminence of growth-related values vis-à-vis the competing ideological and nationalistic considerations. The latter, like consumption, will assert themselves one day. Within the relevant time horizon, they too are best treated as constraints, rather than as arguments in the objective function. The Hong Kong-type policies serve to raise the transformation curve (through more efficient conversion of China's agricultural surplus into capital goods and technology for industry than can be achieved without the markets and services of these colonies) by pivoting upward around the point Y_a; clearly there are limits to such policies. Thus, it is unthinkable for Peking's post-Mao leadership to bring back capitalist practices to the point of undermining the *raison d'etre* for a Communist regime.

The virtue of the command system lies in its recognized efficacy in mobilizing resources for the attainment of some single-minded social objective. Efficiency and finesse in using the resources thus mobilized are not among its strong points. Balassa's recent summary analysis of comparative growth performance makes the point abundantly clear. Socialist economies have savings ratios about twice those of the advanced industrialized western nations (Japan excluded) but showed overall rates of growth that are no higher. At the same time, those market economies (mainly, in East Asia including Japan) with savings ratios comparable to the Socialist rates have enjoyed growth rates more than twice the rates in the Soviet-type economies. Interestingly enough, within the Socialist bloc the apparently great differences in degree of decentralization do not seem to make much difference. However, what needs to be restated in this connection is that, to the large Socialist countries for whom power-aspiration and the command approach make sense, the relevant standard has to do with growth of *MHIS* (including the armament and space industries). In these terms, their

[1] This argument casts doubt on the conventional China scholar's view that in the First Five-Year Plan, Peking unwittingly embraced the Russian model's "industry only" bias, discovered the mistake a few years later, and switched in the early sixties to "agriculture as the foundation." The switch had to do with a shift in emphasis from reliance on traditional inputs to modern inputs centering on chemical fertilizers. The move follows simply from diminishing returns under traditional production possibilities. No reordering of priorities as such was suggested. In fact, Peking's current orthodoxy considers the First Plan period and the readjustment years of 1962–65 as comparable periods noted for their "fairly well-coordinated relations between agriculture, light industry, and heavy industry" (Liu and Zhao, p. 10).

[2] For Chinese statements on the existence of the agricultural bottleneck, see for example, "Second Shanghai Talk on Mao's Ten Major Relationships" (FBIS).

performance has been outstanding, far better than can be achieved in a market economy context.

The Role of Agriculture

The problems inherent in centralized command systems are magnified in agriculture. The vast number of heterogeneous production units, the spatial dimension, the location-specific nature of the parameters affecting planning and management decisions, and the unpredictable intrusion of special "outside" factors such as weather (with its locality- and crop-specific impact), all tend to go against the grain of centralized direction. A measure of decentralization was accordingly granted when collective ownership by members, as opposed to socialist ownership by all people (as in the case of state enterprises), was instituted in agriculture, coupled with a small, private-sector appendage. But the arrangement created problems of its own. The resulting loss in resource mobility and allocative efficiency and in distributive equity also tends to be cumulative in effect. Moreover, a collective farm is not so much a producers' cooperative to capture scale economies for the benefit of its members as it is an arm of the state whose interest is extractive. There is a sizeable and still growing literature on the economics of the Soviet-style collectives, beginning with Ward through Domar, Oi, Clayton, and recently Batra and Bonin.[3] The weight of the opinion seems to say that collective farms need not be inefficient or provide poor work incentive for peasant households, with recent extensions to decision-making under uncertainty and for innovations. The main drawback with these studies, highly regarded in their own right, is that they take resource fixity as given (rather than as a cost of the policy), ignore location-specificity of farming and lack of scarcity prices in the Soviet-Chinese context, and conveniently assume away the interaction dynamics, between the peasant and the state acting through its agents, within the framework of the bureaucratic and command imperatives. It is a little like saying that the U.S. economy need not be short of the perfect competition ideal; only if government were to bring about corrections through a system of taxes, subsidies, and shadow-price signals. We do not really know how to do all this, of course, any more than the Soviets or the Chinese.

In China, management of agriculture from the center would seem to be especially difficult for the elemental fact that scarcity is a more intractable reality. The residual claimancy status of the peasant in the Soviet Union is at least not all bad. If the peasant has poor work incentive, not knowing what is going to be the worth of the work points he is accumulating, he can be in from time to time for pleasant surprises as when an investment, or innovation, or good team effort paid off. In China, with agriculture acting as the binding constraint on industrialization, the imperatives of the development strategy require extractions approximating the maximum possible. This means a consumption standard close to the basic subsistence and invariant over time. That this was the case during 1952–57 is clear from the official statistics showing agriculture's annual own consumption per capita hovering around 92 yuan in the entire plan period (Tang 1968, p. 474).

Since that time, it is a common supposition among China scholars that, in line with its announced policy, Peking has on several occasions taken measures to improve agriculture's terms of trade (including lowering the agricultural tax from about 12% to 5% of gross output), resulting in a narrowing of the rural-urban income gap that widened in the 1950s (e.g., Schran). However, a possibility arises that the measures taken may not have accomplished the stated purpose if the sector suffered productivity declines. To this question we turn our attention in the following section.

Falling TFPI Trend

Gross farm output (*GVAO*) more than doubled (table 1) during the twenty-seven-year period under review, reaching 205% in 1978 (1952 = 100%), a creditable record with an average compound growth rate of 2.9%. In 1952 prices, our estimated 1978 *GVAO* amounted to 82.4 billion yuan. This is to be compared with 145.9 billion yuan in 1978 prices recently released by the State Statistical Bureau (p. 28). A reconciliation is possible, yielding an implicit price deflator for 1978 of 177% (1952 = 100%) which fits right in with the known Chinese source data fragments on farm purchase price index of about 165% in the mid-1970s (Stone;

[3] For these and other citations, see the two more recent articles by Batra and Bonin, as referenced.

Schran, p. 375). The aggregate input index rose even more rapidly, reaching 242% in 1978. Accordingly, the total factor productivity index (*TFPI*) fell to 85% in 1978. A similar picture obtains in terms of the primary factor productivity index, calculated as a ratio of the value-added index to the primary input index (based on labor, land, and capital while excluding current inputs). Consistent with these productivity trends, value added per worker (in constant 1952 prices), too, declined.

We now return to the question whether terms of trade adjustments since the first plan period have resulted in income improvement for the peasant household. One of the side benefits of a detailed growth-accounting study is that it is relatively simple to calculate, from the basic input-output series, value added in constant prices and to see how the value-added series is altered when changes in relative prices are introduced. Value added by agriculture per worker in constant 1952 prices fell from 280 yuan in 1958 to 194 yuan in 1978. Given the 3:1 ratio (in male prime-age equivalent) between population and worker counts in agriculture, our 1958 estimate of 280 yuan per worker is in close agreement with the official per capita consumption (or retention) of 92 yuan cited earlier. Although the two figures are not strictly comparable, similarity in magnitude is reassuring. The decline in the sector's contribution to the national economy per person engaged is noteworthy and points up the crucial role played by modern nonfarm-supplied inputs in sustaining an output growth characterized earlier as creditable. Adjusting for agricultural tax and a price (received) level change from 125% in 1958 to 177% in 1978, we come up with current price estimates of value added per worker of 312 yuan for 1958 and 406 yuan for 1978.[4] Under stable consumer prices facing peasants, these estimates yield a rise in real household income of some 30%, or an average annual rise of 1.3%. This happens to coincide with our earlier estimate (Tang 1979, p. 55) of 1.33% as annual increase in countrywide personal income per capita, as inferred from the estimated macrodata for 1952–77. Both figures seem to stand in harmony (as argued in the same earlier study) with the recent official releases on Chinese per capita income (taken by us to be personal income) which Vice-Premier Chen Muhua placed at US$139 for 1976. The adjustments made to the value added per worker estimates are not complete. There has been some drop in nonfarm input prices. Offsetting this omission are (*a*) failure to deduct depreciation of farm capital, (*b*) failure to take account of collective deductions (for reserves mainly) before distribution to households, and (*c*) rise in consumer prices "paid" by farm households stemming from imputation of value of home consumption by state purchase prices. In sum, it would appear judicious to conclude that, because of falling farm productivity, Peking's terms of trade adjustments on behalf of agriculture probably have accomplished no more than to keep peasant incomes and welfare from slipping further behind relative to urban standards since the first plan period.

The falling *TFPI*—itself a phenomenon unique among the East Asian agricultures—is best understood against this backdrop of virtually stationary peasant household incomes. For, with proper incentive for workers and their collective leaders, it is difficult to see how the massive injection of modern inputs begun since the early 1960s could have failed to raise productivity. It is equally difficult to see this happening outside the larger context of Chinese development strategy and the adjunct command set-up under conditions of severe scarcity. The preceding sections were offered in that spirit. Before concluding this section, we note that the choice of factor income share weights (for the *TFPI*) is fully explained in our larger study and that our results are only moderately sensitive to alternative systems of weights. None of our principal conclusions are overturned by using any of the weights from East Asian agricultures of any time period.

Weather Disturbance and Empirical Evidence

A decade ago Skinner and Winckler advanced a cyclical theory concerning the compliance cycles in rural Communist China. Using Etzioni's frame of reference, Peking's power relations with the peasant may be said to alternate between the normative, the coercive, and the remunerative in approaches. Sharing the view

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[4] For 1958: [69.65 bil. *GVAO* 1958 yuan (= 55.68 bil. *GVAO* 1952 yuan × 1.25) × 0.88 (= 1 − tax rate) − Costs (= 55.68 − 49.91 bil. 1952 yuan of value added) × 1.01] + 178 mil. workers = 312 yuan per worker. Cost inflator of 1.01, from Schran (p. 375).

For 1978: [145.8 bil. 1978 yuan (= 82.37 bil. 1952 yuan × 1.77) × 0.95 (= 1 − tax rate) − Costs (= 82.37 − 50.98 bil. 1952 yuan of value added) × 1.0] + 263 mil. workers = 406 yuan per worker.

about the importance of the rural sector, the late Alexander Eckstein argued plausibly for the existence of policy cycles in China related to harvest conditions (pp. 311–22, 332–38). And Oksenberg spoke more generally about the close relationship between Chinese politics and the "agricultural cycle" as an explanation of political changes in the PRC (pp. 107–8). Though differing in emphasis and theoretical underpinnings, the cyclical notions of all these writers are complementary. They give rise to economic policy periodicity alternating between radicalism and pragmatism and impinging on organizational and incentive correlates in agriculture.

It is widely thought that such policy gyrations must have left their impact on agricultural performance. To our knowledge, however, there has been no serious attempt to quantify the relationship. The key problem, as pointed out by Eckstein (p. 321), has to do with the difficulty in determining the extent to which the quality of any one harvest is affected by weather, on the one hand, and by policy, on the other. The sticking point has been weather. There is the usual dearth of Chinese data, although with respect to weather we are relatively well off, thanks to the U.S. intercept program. The real problem lies in our ignorance of crop-specific, location-specific weather and yield relationships in agriculture. And as it impinges on the farmer, weather is a complex multidimensional phenomenon that defies quantification that is meaningful and operational. Thus, there is no national agricultural weather index for any country, the U.S. included. In what follows we shall attempt a crude separation of the influences of weather and policy cycles.

In terms of basic methodology, we take agricultural output in any given year to be determined by (*a*) the amounts of inputs (suitably aggregated) utilized, (*b*) the technology employed whose level bears on input productivity and whose change over time is represented by a secular productivity trend, (*c*) the economic milieu whose critical dimensions, organization and the play of material incentive, oscillate with the policy cycle, and (*d*) weather, treated as a random phenomenon. The conceptualization enables us to employ standard time-series decomposition techniques to separate out influences of weather and policy cycles. As before, we identify performance with productivity instead of output, a move that allows abstraction from changes in inputs.

In figure 2 we present a categorical weather index for each of the years classifying them as "good," "average," or "poor" weather years

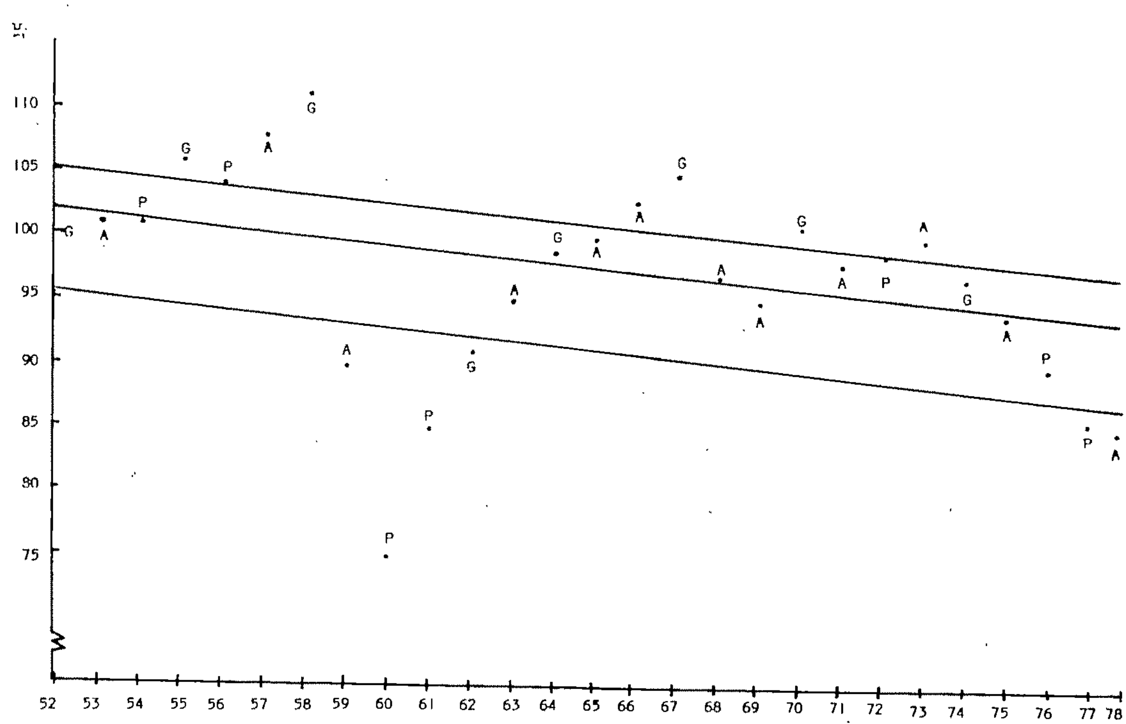

Figure 2. Weather-specific trend lines in *TFPI* ($Y_c = 95.77 + 6.29D_1 + 9.33D_2 - 0.32X$)

for the crops. There were eight good years, twelve average years, and seven poor years during 1952–78. First, separate trend lines were fitted to the three classes of observations without restrictions to see whether the null hypothesis of common slopes is tenable. All three slopes turn out to be in the -0.3 to -0.4 range with insignificant t-statistics. Weather dummies are used next. They enter as intercept dummies with the regression yielding an R-square of .32 and t-statistics on all the coefficients significant at conventional levels. The intercepts for the poor, average, and good years are, respectively, 95.8, 102.0, and 105.1 and the common slope $-.317$. It will be remembered that *TFPI* is the time series with the reference of 100% in 1952, which is also the origin for the trend equation. The empirical evidence on the behavior of the three weather-specific trend lines is of considerable interest because whether or not the lines converge over time constitutes a basis for testing the validity of Chinese claims of having successfully "weather-proofed" their agriculture.

To wring additional information from the data, we applied the Cochrane-Orcutt successive differencing iteration technique in fitting curves to the observations. The procedure is designed to remove serial correlation from the error term iteratively until marginal gain becomes too small to justify further computing. Weather intercept-dummies were used as before. What the procedure amounts to is to fit curves that swing up and down with the (weather-specific) data. With each successive iteration, the residuals come closer to being nonautocorrelated. If our time-series model is $Y = T + C + W$, then the fitted values may be said to represent weather-specific $T + C$ curves. Deviations about these fitted curves may be examined for indications of imbalance between the early and late years as may be brought about by the common-slope restriction. If in effect there was convergence but the fitted lines are required to have common slope, for the poor-weather line, negative deviations would dominate in the early years and positive deviations in the late years. The opposite holds for the good-weather line. No such imbalance can be detected. In sum, the available evidence seems to support the inference that the data do not reject the hypothesis that the weather-specific trends in *TFPI* are parallel. This is actually a strong test because the more plausible model, $Y = T \times C \times W$, would produce arithmetic convergence in the case of downward trends, even if weather's (proportional) effect remained constant. We further infer, therefore, that the weight of the evidence appears strong that the Chinese have not in fact been able to control the influence of weather on agriculture. Accepting the parallel weather-specific trends, it is clear that weather as such has had rather modest influence on agricultural performance in China (unlike Russia and smaller countries such as Japan), as shown by an average difference of only six percentage points between poor and average years and a mere three percentage points between good and average years.

This is at great variance with our expectations. The collective-socialist organization of the countryside, the vast water-control projects, and the concurrent modernization embodying genetic, biological, chemical, and mechanical elements—all are ingredients for making man and his agriculture more resistant to the vagaries of nature. During the Great Leap Forward, excessive zeal and haste did produce manmade errors in infrastructure that compounded the effects of adverse weather in 1960–61. But these problems have long been corrected. Perhaps three speculative offsetting factors are worth stating: (*a*) increased intensity with which land is used reducing the latitude between harvesting and planting needed to cope with weather uncertainty; (*b*) shifts in cropping patterns dictated by Peking's push for local and regional self-reliance and which proved to be incongenial to the natural environment; and (*c*) the command system tends to work less well when farming becomes more sophisticated, requiring a more intricate supply system that involves many producers outside agriculture and demands a high degree of coordination.

Policy Cycle in Agriculture

By taking deviations from the weather-specific linear trend lines, we eliminate trend and the average influence of weather by category. What the procedure leaves are agricultural cycles and a residual irregular component which may be attributed in part to discrepancies between the actual weather conditions of a given year and the average conditions of the weather category to which the year belongs. The latter irregular or random component is "eliminated" by applying ordinary moving averages to the deviations. Figure 3 shows the

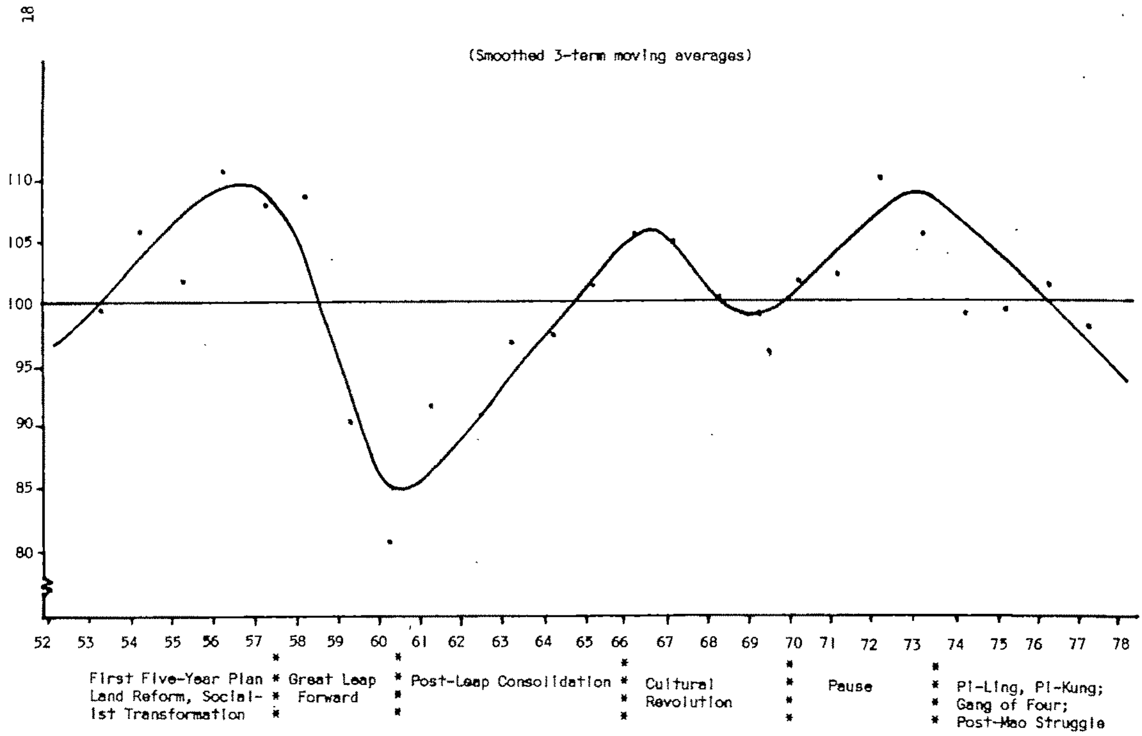

Figure 3. The agricultural cycles in *TFPI*

smoothed path drawn freehand through the (three-term) moving averages. Deviations can be arithmetic or relative, depending on whether one employs an additive or multiplicative time-series model. It makes little difference which form is adopted. In figure 3 the relatives are shown as is consistent with common practice.

An alternative method is to make use of the fitted weather-specific, trend-cycle term from the Cochrane-Orcutt iteration and to divide the term by the weather-specific linear trends. The resulting ratios trace out cyclical configurations similar to what was obtained earlier. Because the first procedure is more straightforward, the results presented here are based on it. These results in figure 3 clearly show that agricultural (*TFPI*) productivity cycles coincide precisely with the known policy or political cycles in China. Productivity rose during the Socialist transformation and First Five-Year Plan period, aided in part by completion of recovery back to prewar peaks and by the taking-up of the then existing slacks in resource use in the form of, for example, fragmented land holdings. Buck once thought that such slacks represented perhaps a potential increment of 25% in output (p. 203). Starting at about 100% in 1952–53, the upswing peaked at about 108% in 1957–58. The downswing brought about by the Great Leap Forward reached the trough in 1960 at around 85%. Recovery followed during the readjustment or consolidation period. Completion of post-Leap recovery was accomplished around 1964; the upswing beyond that point was short-lived, however, peaking at about 106% in 1966 as the cultural revolution began to gather momentum. The drop in agricultural performance turned out to be surprisingly mild as the celebrated radical movement ran its course, bottoming out at just under 100% in 1969. The pause that followed brought agricultural productivity (*TFPI*) back up to about 108% in 1972, only to have the upswing aborted the following year, which saw the beginning of a radical revival launched under the guise or symbolism of an anti-Lin, anti-Kung campaign. As the ailing top leaders loosened their grip on the affairs of the state and the radicals, now known as the "Gang of Four," consolidated their power, agricultural performance continued to suffer. By 1975–76, *TFPI* had dropped back down to 100% and continued to fall as Mao's death and the succession struggle that followed it further weakened order and disrupted economic activities. The slide appeared to continue well through 1978

(when the productivity index reached an estimated low of 85%, with the cyclical relative, however, standing at about 94%) although grain and total agricultural production recovered sharply from the stagnation of 1976–77, thanks to improved weather and massive increases in inputs (especially chemical fertilizers).

Conclusions

The quantitative cyclical record, crude as it is, suggests that, historically, Chinese peasants have responded in a rather predictable and speedy manner to Peking's policy gyrations which impinge on them economically. The close coincidence between agricultural cycles and policy cycles also points up a basic policy dilemma, a dilemma more intractable than in Russia because of China's elemental reality of scarcity. In Eckstein's frames of reference, the clash between the household and the planner, the interplay and clash between ideology and scarcity, the alternations (in Skinner's words) between normative, coercive, and remunerative policy instruments—all are much more immediate and relentless in the PRC. These realities, stemming from the country's unfavorable initial conditions, are also, in our view, at the root of the Chinese secular decline in agricultural productivity, and serve to magnify the problems inherent in the development design and the related command economic system.

It is noteworthy, however, that observed agricultural cycles have become significantly more damped since the Great Leap. Although the cultural revolution was much more far reaching and of greater import politically, its economic impact on agriculture turned out to be almost negligible as compared with the shocks created by the Great Leap. Strenuous efforts were indeed made to keep the cultural revolution from spilling into the economy. Eckstein saw in this encouraging signs of "learning effects" at work (p. 320). Deng, the pragmatist, presumably would take such lessons even closer to heart as he experiments with bold programs never before attempted.

Weather does not seem to loom as large as many have thought as a factor with respect to total output, even less in relation to total factor productivity. This view is consistent with the longer historical record, as well. China is a large and climatically diverse country. Famines tend to be localized and become disasters that attract the attention of chroniclers, for lack of transport and effective central government. It is something of a paradox that, the government's Herculean effort to modify and control "nature" notwithstanding, weather appears to matter as much as ever, in terms of its measured impact on agricultural productivity. The "explanations" that we offer are speculative; more definitive answers await further research.

References

Balassa, Bela. "Proposals for Economic Planning in Portugal." *Revista Economia.* Universidade Catolica Portuguesa, 1977, pp. 117–124.

Batra, Raveendra N. "Technological Change in the Soviet Collective Farm." *Amer. Econ. Rev.* 64(1974):594–603.

Bonin, John P. "Work Incentives and Uncertainty on a Collective Farm." *J. Compar. Econ.* 1 (1977):77–98.

Buck, John L. *Land Utilization in China.* Chicago: University of Chicago Press, 1937.

Chen Muhua. "Planning to Achieve the Four Modernizations." *People's Daily,* 11 Aug., 1979, p. 2.

Chenery, Hollis and Alan Strout. "Foreign Assistance and Economic Development." *Amer. Econ. Rev.* 56 (1966):679–733.

Chiang, Alpha C. and John C. H. Fei. "Maximum-Speed Development through Austerity." *The Theory and Design of Economic Development,* eds. Irma Adelman and Eric Thorbecke, pp. 67–92. Baltimore: The Johns Hopkins Press, 1966.

Eckstein, Alexander. *China's Economic Development.* Ann Arbor: University of Michigan Press, 1975.

Foreign Broadcast Information Service. "Second Shanghai Talk on Mao's Ten Major Relationships." 25 Feb. 1977, p. E6.

Fisher, Irving. *The Theory of Interest.* New York, 1930.

Lewis, W. Arthur. "Economic Development with Unlimited Supply of Labor." *Manchester School* 22 (1954):139–91.

Liu, Guoguang, and Renwei Zhao. "Socialist Economic Planning and the Market." *Beijing Review,* 6 July 1979, pp. 37–41.

McKinnon, Roland I. "Foreign Exchange Constraints in Economic Development and Efficient Aid Allocation." *Econ. J.* 76(1964):388–409.

Oksenberg, Michel. "Political Changes and Their Causes in China, 1949–72." *Polit. Quart.* 45(1974):95–114.

Ranis, Gustav, and John C. H. Fei. "A Theory of Economic Development." *Amer. Econ. Rev.* 51(1961): 533–65.

Schran, Peter. "China's Price Stability: Its Meaning and Distributive Consequences." *J. Comparative Econ.* 1 (1977):367–88.

Shi, Zhengwen. "Readjusting the National Economy:

Why and How?" *Beijing Rev.*, no. 26 (1979), pp. 13–23.

Skinner, G. William, and Edwin A. Winckler. "Compliance Succession in Rural Communist China." *Organizational Change* (1969), pp. 410–38.

Solow, Robert M. "Technical Change and the Aggregate Production Function." *Rev. Econ. and Statist.* 39 (1957):312–20.

State Statistical Bureau. "Communique on Fulfillment of China's 1978 National Economic Plan." *Beijing Rev.*, 6 July 1979, pp. 37–41.

Stone, Bruce. *A Review of Chinese Agricultural Statistics, 1949–1978.* Washington, D.C.: International Food Policy Research Institute, forthcoming.

Tang, Anthony M. "Policy and Performance in Agriculture." *Economic Trends in Communist China*, eds. Alexander Eckstein, Walter Galenson, and T. C. Liu, pp. 459–507. Chicago: Aldine Publishing Co., 1968.

———. *Food and Agriculture in China: Trends and Projections, 1952–77 and 2000.* Mimeographed. Washington, D.C.: International Food Policy Research Institute, 1979.

New Directions in China's Agricultural Imports

Frederic M. Surls

Agricultural imports of the People's Republic of China rose sharply between 1977 and 1979. Grain imports increased to record levels, coarse grains appear to be emerging as a regular import item, China's traditional net export surplus of soybeans vanished, and imports of vegetable oils were substantial. Sugar imports were also well above historical averages and cotton imports reached a record high. This expansion of agricultural imports has been but a small part of a major increase in PRC foreign trade, an increase which has raised total trade in nominal terms by nearly 60% between 1976 and 1978, has seen a large program of complete plant and technology purchases, and has programmed substantial trade deficits for coming years, deficits that will be covered by a sizeable accumulation of foreign debt.

The long-run implications for agricultural imports of developments in the past two years are by no means certain. On the one hand, demand developments in China suggest growing pressures to further increase agricultural imports. On the other hand, limitations on China's ability to export, growing debt repayment pressures during the eighties, and China's new seriousness about acceleration of the growth of agricultural production suggest that the Chinese leadership does not desire substantial further increases in agricultural imports.

This paper identifies and examines some of the major factors that will shape China's agricultural imports during the remainder of the current ten-year plan (1976–85). China's growing imports of textile fibers will not be treated, because they involve, at least in part, a separate set of explanatory variables. The factors discussed below include the aggregate supply-demand balance for key agricultural commodities, the role of state procurements, and foreign trade policies and export growth rates. Each of these has a major bearing on future trade and each is shifting in important but unquantifiable ways.

The discussion includes a qualitative evaluation of the future impact of each of these factors on trade and of the future direction of change of trade in key commodities, particularly grains and oilseeds. This evaluation is based on preliminary results of projection work now in progress and is presented largely for purposes of illustration. The key feature of forecasts of China's agricultural trade is uncertainty. Basic data are lacking and our understanding of both economic structure and past and current economic policies is so poor that the range of possible outcomes is wide.

China's Agricultural Imports

During the past two decades, the PRC was a major purchaser of a limited range of agricultural commodities—grains (particularly wheat), cotton, rubber, and sugar. Overall, agricultural commodities have accounted for between 20% and 40% of all PRC imports during this period. China's imports of food began on a major scale in 1961, the result of the sharp decline in agricultural production following the Great Leap Forward. Major food imports during the sixties were limited to wheat and sugar.

During the seventies, particularly from late 1972 onward, both the scope and annual variability of Chinese agricultural imports increased. Grain imports reached record levels in 1973 and 1974 and the first significant purchases of soybeans and soybean oil came in 1973. Imports of these products fell sharply in 1975 and 1976 as China reduced its overall import levels because of improved production, a substantial trade deficit, and domestic political turmoil. Imports again rose during 1977.

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Grain imports reached record levels in both 1978 and 1979, soybean imports resumed, and substantial amounts of soybean oil were imported in each of the three years from 1977 to 1979. At least some of the coarse grains imported in 1978 and 1979 were intended for feed use, a potentially important new development in China's grain import program.

The policies behind these purchases have never been elaborated by the Chinese. The beginning of the program in 1961 was clearly the result of dire necessity; at some point afterward, the leadership decided to continue to use imports to supplement state procurements of key commodities from rural areas rather than to increase pressures on the rural sector during years of poor production. This policy was limited in scope, however—restricted at first primarily to grains and, after the first several years, never carried to the point that it eliminated China's net surplus in agricultural trade. This surplus has financed an important share of China's nonagricultural imports.

It appears that the import surge from 1972 to 1974 resulted in part from a liberalization of agricultural import policy—one of the steps taken at that time to reemphasize economic development and modernization and to increase the role of foreign trade. Those steps were temporarily disrupted by the economic and political shocks of 1975 and 1976. But the increase in agricultural imports since then appears to be rooted in policy decisions initially made and tentatively implemented in 1972.

It should be emphasized that the expansion of food imports to date is minor compared with changes in the rest of China's foreign trade. The country has continued to be a net agricultural exporter, the range of imported items remains narrow, and, unlike other imports, there has been no change in China's methods of financing agricultural purchases. These continue to be on a cash basis, with the exception of 12- and 18-month credits for purchases of grain from Australia and Canada, a practice in use since the sixties.

Problems of Explaining and Forecasting Agricultural Trade

It is one thing to describe and generally discuss China's agricultural imports. Attempting to explain past trade behavior and to predict future trade levels is quite another matter. Neither trend analyses nor modeling efforts offer a great deal of help in attempting to analyze trade in individual commodities. Presently available production series for individual commodities are largely estimated and subject to large margins of error. In many cases, production series are based on no more than one to two reports from Chinese sources over the past twenty years—e.g., those for coarse grains and oilseeds (USDA, pp. 31–33). The balance of estimates for the series are based on judgment with only the crudest consistency checks available. In other cases, e.g., total grain production, more complete data are available from Chinese reports but considerable question remains about statistical definitions used by the Chinese, as well as about the quality of Chinese data in a period when the statistical system was only partially functioning. New information released in 1978 and 1979 has greatly reduced questions about current levels of production but uncertainty about levels for earlier years and hence about past trends and annual fluctuations remains.

On the utilization side, virtually no data are available for the past two decades. Hence, independent assessment of these trends is subject to an even greater margin of uncertainty. As a result of these problems, estimating future imports, by starting from an analysis of past trends, is subject to wide margins of error. The small size of trade in proportion to domestic production and utilization greatly compounds this problem.

Attempts to model past trade behavior face even greater difficulties. Although a priori models can be specified, problems with the production series and the absence of data on other critical variables, such as incomes, stocks, state procurements, and domestic prices, limit the value of efforts to quantify relationships. Uncertainty about the timing, nature, and extent of past policy changes affecting agricultural trade further complicates modeling efforts.

Even if past relationships could be quantified, they would be of limited value in forecasting future trade. The domestic and foreign economic policy changes since 1977 are enormous and in many respects represent an entirely new direction for the Chinese economy. Consequently, both supply and demand for agricultural products and demand for agricultural imports have shifted to an unknown extent.

Attempts to analyze quantitatively agricultural trade are not hopeless, however. New

data are becoming available, permitting both pegging of current levels and improving historical series. But productive work in this area is, for the most part, several years away. In the meantime, we are left with judgmental analysis based on very limited information.

The Domestic Demand-Supply Balance

Of the factors shaping future Chinese agricultural imports, the most obvious are shifts in the aggregate domestic supply-demand balance for key commodities. Clearly, the major reason behind China's ambitious plans for expanding agricultural production between now and 1985 is a substantial planned expansion of demand. Among the factors potentially affecting demand growth during the period are falling population growth rates, rising real incomes, and new livestock programs.

Population Growth

China's population growth rate should drop over the next six years. Chinese plans have targeted a 0.5% per annum birth rate by 1985, implying a planned average growth rate of 0.8% per annum for the 1978–85 period. Although a drop of the growth rate to this level is unlikely, Western demographers do project substantial reductions. One widely used population series shows growth rates dropping from a 1970–77 average of 2.2% per year to a 1.3% per year average between 1978 and 1985 (CIA, p. 5). Such a reduction significantly eases demands on agriculture. Using this series, for example, the annual growth of grain production required to maintain per capita consumption levels drops from an average of 4.6 million tons per year between 1970 and 1977 to 3.1 million tons annually between 1978 and 1985; the figure will drop to less than 2 million tons annually if Chinese population targets are met. Other developments, however, will more than offset any reduction in demand pressure due to slower population growth.

Income Growth

There was little improvement during the two decades between 1957 and 1977 in either per capita income or per capita consumption of major agricultural products—grains, edible oils, and meat—or cotton textiles. But growth of income over the remainder of the ten-year plan period will be a major source of increasing demand for these products.

Comprehensive income data are not available. But agricultural procurement price increases and larger procurements from the rural sector, together with wage increases in the urban sector, already have expanded purchasing power. The gains in income appear to have been concentrated in the rural sector; per capita rural income from the collective sector increased by nearly 14% in 1978 and a further 12% to 14% increase is planned for 1979 (Foreign Broadcast Information Service: PRC, hereafter cited as FBIS, 2 July 1979, p. L-14 and FBIS, 3 July 1979, p. L-6). The effects of two major wage increases, together with a recent subsidy for basic food items in the urban sector, have been at least partially eroded by price increases in both 1978 and 1979. On balance, however, it is clear that significant increases in real per capita income, perhaps on the order of 4% to 5% per year, have been targeted for the 1978–85 period, with the larger share of these increases planned for the early part of the period.

Increases of this magnitude will accelerate the growth of domestic demand for agricultural products. At China's current level of development, income elasticities for most basic agricultural products are still substantial. In the case of grains, per capita direct consumption can be expected to rise; in particular, a considerable expansion of demand for wheat and rice can be expected. Demand for coarse grains and tubers for direct consumption will grow much more slowly. Large increases in demand also can be expected for oilseed products (such as oils and beancurd), sugar, meat, and fruits. Most of these commodities are already in short supply at current income and price levels, as evidenced by widespread rationing and illegal price increases.

This growth of demand resulting from higher incomes is a major new development in China's aggregate supply-demand balance for agricultural commodities and is clearly a major factor behind new efforts to increase the rate of growth of agricultural production. However, uncertainty about actual income growth rates and relevant elasticities leaves a considerable range for projections of demand growth.

New Livestock Programs

New Chinese plans emphasize diversification of agriculture, in particular, development of livestock production for both domestic consumption and export. The nature and full scope of plans in this area are unclear. Full agreement may not yet have been reached among the Chinese leadership; the feasibility of rapid livestock expansion is still being debated in the Chinese press.

What is known about plans for livestock development involves both grassland improvement for beef cattle and sheep and expansion of hog and poultry operations in traditional agricultural areas. The latter is of particular interest because of its great potential to increase demand for coarse grains and protein meals.

Pork is the dominant meat produced, accounting for as much as 90% of China's very low level of meat production, reportedly about 7.5 kilograms per capita (*Renmin Ribao*—People's Daily—hereafter cited as RmRb, 9 Aug. 1979, p. 6 and FBIS, 31 Aug. 1979, p. L-29). Hogs in China traditionally have been and remain today largely a by-product of other farming and rural household activities. They are fed primarily on household and plant residues and by-products and on forage, with only minimal use of grain, oilmeals, or other feeds. Weight gain is therefore slow and slaughter weights low. China currently slaughters only about 50% of its annual hog inventory, less than one-third of the U.S. rate. Past policies have overemphasized inventory numbers, with the result that the current slaughter rate is about 30% below that of fifteen years ago (RmRb, 15 Nov. 1979, p. 2). As a result, per capita meat consumption has increased little despite rapid growth of hog numbers.

Any attempt to accelerate the growth of production of meat and animal or poultry products will require more intensive feeding of livestock. One version of the 1985 plan called for doubling of meat production by 1985, to be achieved with only a 30% increase in livestock numbers (FBIS, 31 Aug. 1979, p. L-29). This indicates planned sharp increases in slaughter rates and higher slaughter weights, both requiring substantially more feeding of animals. The grain requirements of such a program are large, although current feeding practices may be so inefficient that the response at the margin to increases in feed may be substantial. Even under conservative assumptions, however, the grain requirements of such a program would be enormous—an additional 25 million to 40 million tons of feed annually by 1985.

One important variable in the livestock program will be the nature and location of new hog and poultry facilities. One proposed feature of the livestock program has been stress on production in urban areas, with calls for achieving urban self-sufficiency in meat production. Rapid expansion of hog and poultry production in this sector would require larger facilities and would be particularly feed intensive. Although there are indications that the PRC is reviewing the scale of the livestock expansion program, a considerable growth of both hog and poultry production will be attempted. The likely per capita income growth rates together with a high income elasticity of demand suggest that demand for meat and meat products will expand by perhaps 40% to 50% between 1978 and 1985. Unless livestock production grows substantially, China will have to impose even tighter rationing or substantial price increases over and above the increase in livestock product retail prices of approximately 30% implemented in November 1979. The livestock expansion program will clearly strain domestic supplies of both grains and oilmeals. Just how much will depend on the actual rate of expansion of the livestock sector, the nature of this expansion, and the marginal response of meat production to increased feed use.

Growth of Production

Given accelerated growth of demand, the growth of agricultural production between 1978 and 1985 is critical to import prospects. This paper will not attempt to present a detailed projection of growth rates for agricultural products, and the wide range of uncertainty surrounding production forecasts should be kept in mind. In general, growth of crop production should accelerate as a result of a combination of increased input supplies, improved incentives, lessened central control with a resulting increase in efficiency, and accelerated technological progress. But the overall growth of agriculture is likely to be less than the 4% to 5% annual growth rate planned by the Chinese. Moreover, production of key products, in my judgment, will not keep pace with the growth of demand, thus increasing

pressures either to import more agricultural products or to alter domestic plans.

Specifically, grain production is likely to fall well short of the 1985 plan level of 400 million tons, a 4.4% average annual rate of increase between 1978 and 1985. The growth of wheat production may about match the growth of demand, but the current production-consumption gap is not likely to decline and may in fact increase somewhat. Coarse grains may well be the fastest growing component of grain production, but demand growth resulting from the livestock program is likely to outstrip the growth of production. Rice production appears likely to grow at a somewhat slower rate than either wheat or coarse grains and will not relieve demand pressures on wheat supplies.

Oilseeds are a second critical category. An early version of the Chinese plan implied a planned 9% average annual rate of growth of production of oilseeds between 1978 and 1985 (FBIS, 31 Aug. 1979, p. L-29). This does not include soybeans, which the Chinese include with grain and for which no separate plan target is available. Increases in oilseed production are likely to fall short of this target and China's demand for vegetable oils will continue to exceed its extremely short supply.

Increased demand for oilmeals due to the livestock program is another important part of the growth of Chinese demand for soybeans and other oilseeds. As nearly as can be determined, protein meals now constitute a very small share of feed rations. Although soybean production should increase, mainly through acreage expansion in the Northeast, the growth of production of soybeans and other oilseeds is unlikely to generate the required meal supplies. This shortage may well constitute the major bottleneck for the livestock program.

Strictly on the basis of this assessment of likely supply and demand developments in China between now and 1985, wheat imports probably will not decline, coarse grain imports should increase somewhat, and either soybean or vegetable oil and meal imports may expand substantially. That last development may be the major change in China's agricultural imports during the next six years. For soybean rather than meal and oil imports to increase, China's crushing capacity will require a considerable expansion and modernization, because much of the output of existing facilities is unsuitable for feed use and is used instead for fertilizer.

Growth of State Procurements

Growth of production is a necessary, but not a sufficient, condition for meeting state requirements for grains and other agricultural products. The urban/industrial sector depends in large part on state procurements from the rural sector; imports of grain and other agricultural products are used mainly to supplement such supplies. For most farm products, then, import demand depends more directly on the procurement supply-demand balance than on the aggregate supply-demand balance for the economy.

Demand for agricultural products in the urban/industrial sector will grow substantially between now and 1985, although perhaps at a slower rate than that of the economy as a whole. Natural rates of population growth in major urban centers already are lower than for the country as a whole and further reductions will be more difficult to achieve. At the same time, reduced controls over rural-urban population movement are probable. Therefore the urban population growth rate will likely increase rather than fall. As noted above, growth in real per capita incomes may be below that for the rest of the economy. But per capita demand for preferred food grains will increase. Additionally, the extent and pace of livestock developments in urban and suburban areas will have an important bearing on future grain demand, although probably not in the next several years. But if an urban livestock program is pushed rapidly, urban sector feed grain demand will be substantially higher by 1985.

While demand from the urban sector continues to grow, two additional sources of demand will compete for state procurements. The Chinese leadership has indicated a desire to increase state stocks of grain; that program probably will take on a higher priority in the future. More important, new agricultural policies emphasize increasing regional specialization as a means of raising agricultural productivity and increasing production of livestock and economic crops. If this shift from past emphasis on local self-sufficiency is to work, the state will have to guarantee supplies of essential food items to areas that increase their degree of specialization. This will require a substantial increase in resale of state procurements to the rural sector of the economy.

On balance, then, demand for state supplies of agricultural products can be expected to

increase considerably between now and 1985. In recognition of this, the 1985 plan calls for a 60% increase in state procurements of grain (FBIS, 6 July 1978, p. E-5). This is a 6% average annual growth rate compared to a planned 4.4% increase in grain production and indicates a planned marginal procurement rate of about 35% during the 1978–85 period compared to an average rate which is probably now no higher than 25%. Much of the planned increase in procurements is intended for resale to rural areas. No data are available for procurements of other crops, but comparable high marginal procurement rates are likely planned.

Achieving this increase in procurements will depend on the overall growth of crop production. But it also will depend heavily on the procurement response to higher price incentives and on the success of state plans for development of commodity bases—specific regions which have been targeted for large state investment and which are expected to have substantially above-average marketing rates. The commodity base program is critical to efforts to achieve substantial increases in procurements.

The increase in procurements over the next six years is likely to fall short of plans. Furthermore, since the growth of agricultural production should be below planned levels and the additional supplies which can be generated by the commodity base program over the next few years are open to question, procurements will most likely fail to keep pace with the growth of demand between now and 1985. This will be another factor adding to increased pressure to import agricultural products.

Foreign Trade Plans and Export Growth

China's trade policies and the future growth of export earnings will have an important impact on the future pattern of Chinese agricultural trade. The PRC is now running a trade deficit and has programmed a growing level of foreign debt to finance imports of complete plants, equipment, and technology. At the same time, strenuous efforts are underway to increase exports, which will become increasingly important as China's debt service costs rise during the eighties.

Plans for agricultural trade never have been made public; but public statements have emphasized expanding agricultural exports, indicating a probable intention to continue as a net agricultural exporter. Trade plans well may envision holding agricultural imports at current levels or even reducing them as new production policies take hold. This would permit a rising agricultural trade surplus and continued use of the agricultural sector to finance nonagricultural imports, although the share of agriculture in total trade would decline with more rapid growth of nonagricultural trade. There have been indications of plans not only to increase traditional agricultural exports, including soybeans, but also to expand the level of grain exports, including coarse grains and, for the first time, wheat.

Such plans could be realized if production grows rapidly enough or if the growth of domestic demand is held down. Examination of domestic developments, however, indicates to me pressures to raise agricultural imports and a growing tension between domestic plans and foreign trade intentions. This tension will increase if the growth of Chinese exports lags and the Chinese leadership attempts to hold down debt levels.

There is no way to project how such tensions will be resolved. It is unlikely, however, that the full burden of adjustment will fall on agricultural imports. Although growing domestic excess demand does not directly translate into higher import levels, it does generate both price pressures and increased rationing as well as pressures to curb the growth of domestic incomes, unless demand is allowed to spill over into higher import levels. The willingness and ability of the leadership to adjust consumption levels to available supplies in the event of a shortfall is open to question and the potential costs to the economy of attempting to do this are greater than in the past. Therefore, excess demand pressures seem likely in fact to translate into higher future imports of key agricultural commodities and a resulting reduction in the size of the agricultural trade surplus.

Conclusions

This survey of factors and developments affecting the future of China's agricultural imports should, in addition to presenting one import scenario, suggest several things. First, a complex set of economic and policy variables will be determining future import levels. Demand growth, in particular, will have to be

recognized more explicitly, as will the role and importance of state procurements in determining import levels. Second, the general factors described here may cause somewhat greater variability in annual imports than in the past. This possibility is reinforced by the apparent importance of areas such as the Northeast in plans to increase state procurements of grains and soybeans. These areas likely are subject to greater yield and production fluctuations than is the nation as a whole. Finally, this survey should clearly illustrate the lack of hard information about trade-determining factors and their relative importance and the wide margin of error which should be expected in attempting to forecast Chinese trade. The uncertainty that this generates should be kept clearly in mind when evaluating PRC trade forecasts. This uncertainty is reinforced by recognition of one implicit assumption made throughout the analysis—general stability of economic policies between now and 1985. A severe plan failure or a change of leadership could lead to a sharp reorientation of both domestic and foreign economic and political policies, with a resulting major impact on agricultural trade.

References

Renmin Ribao (People's Daily). Beijing, China, 9 Aug., 15 Nov. 1979.

U.S. Central Intelligence Agency. *China: A Statistical Compendium*. Washington, D.C., July 1979.

U.S. Department of Agriculture. *People's Republic of China, Review of 1978 and Outlook for 1979*. Washington, D.C.: ESCS Supplement No. 6, World Agr. Situation, No. 18, June 1979.

U.S. Department of Commerce, National Technical Information Service, Foreign Broadcast Information Service (FBIS). "Daily Report: People's Republic of China." Springfield, Va., translations of various Chinese radio broadcasts.

Chinese Agriculture: Development, Production, and Trade: Discussion

Nicholas Lardy

Although a smaller and smaller share of China's gross domestic product originates in the agricultural sector, the pace of agricultural development has and will continue to be a main determinant both of changes in the Chinese standard of living and of China's overall pace of modernization. Because of the role of agriculture in supplying the major wage good and the complex interrelationships between agriculture and the rest of the economy, great efforts have been made in the West to measure the performance of China's agricultural sector. These efforts have ranged from the construction of independent output series for food grains to more complex efforts to measure intertemporal changes in aggregate per capita caloric consumption or in total factor productivity in agriculture. The major weakness of most of these studies is a lack of adequate underlying data of all types and, most particularly in the case of total factor productivity calculations, of sufficiently disaggregated time-series data for both outputs and inputs. Thus, the drive to present empirical findings can be satisfied only by resorting to a large number of quite arbitrary assumptions. Unfortunately, the most crucial of these assumptions all too often are buried in the footnotes to appendix tables. Because the empirical results presented are entirely a function of the assumptions made, the texts of these papers, in my view, should be devoted to establishing the plausibility of the assumptions made and to examining the implications of alternative assumptions. I cannot emphasize too strongly that, given the paucity of basic data in most cases, plausible arguments can be made for alternative sets of assumptions that have profoundly divergent analytical assumptions. My intention below is simply to raise a number of issues with the hope of suggesting that the secular decline in total factor productivity in Chinese agriculture discussed by Tang should be regarded as a hypothesis rather than an established fact (Tang 1980). These questions fall into several categories.

First, there are several important theoretical questions that deserve close examination. The simple take it or leave it proposition offered by the paper with regard to the methodology employed is not acceptable if one proposes, as this paper clearly does, to draw analytical conclusions from the empirical results. Many of the assumptions necessary for the sound application of the basic Cobb-Douglas methodology simply do not appear to be valid in Chinese agriculture. For example, in the absence of a production function estimate of the elasticity coefficients of the inputs, factor shares from other countries must be used. Given the unusually low land to labor ratio imposed by China's basic resource endowment, one might ask whether other countries' factor shares should be used with such equanimity. Given the underlying relative scarcities in China, the necessary assumption of neutral technological change over the past thirty years is also open to question. It is far more likely that technical change has been sharply biased in a labor augmenting/land saving direction. Thus, even if the initial factor shares were a good approximation of the underlying production elasticities, there is a strong presumption that after technical change accelerated in the mid-1960s, there would be systematic gaps between the production elasticities and factor shares. Thus the use of constant factor shares may bias the results.

Second, there are a number of conceptual errors in the construction of the input indexes that are used. Tang, for example, makes the

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usual assumption that the growth of the capital stock is a measure of the growth of capital services, ignoring the distinct probability that capital services have grown at a significantly lower rate because of shortages of repair facilities, implements, and fuels for various types of farm machinery. There also appears to be some double counting—the index of land inputs is adjusted upward to reflect the increment in yield resulting from irrigation, but diesel and electric power irrigation equipment are also counted in the capital stock. Finally, the labor index is constructed on the assumption that the agricultural labor force is a constant share of the rural population, ignoring a sharp upward trend in rural primary and secondary school enrollment, the rapid growth of nonagricultural employment of rural residents in small-scale industry, and the probable deployment of a growing share of the rural labor force to both rural housing construction and to what the Chinese refer to as farmland capital construction. Again, some of the labor would appear to be double counted because it has already been counted implicitly in the growth of irrigated area.

Third, more recent data suggests that there may be significant errors in the estimates of certain physical inputs and perhaps in gross agricultural output as well. The estimated quantities of chemical fertilizer and insecticides for recent years are higher than the more recently released official data. Part of the discrepancy may be due to quality differences but there should be an across-the-board reexamination of the input estimates to compare them with the newly released official data. On the output side the reconciliation of Tang's estimate (in 1952 prices) of the value of agricultural output in 1978 with the more recent official data (in 1970 prices) requires an implicit price deflator for 1970 of 177 (1952 = 100). Although considerably more research is required, some evidence suggests that the actual deflator is somewhat smaller, perhaps in the range of 150–160. If further research verifies this smaller price deflator, more than half the postulated decline in total factor productivity between 1952 and 1978 would be expunged.

The comments above are directed primarily to the issue of changes in factor productivity over the long run between the 1952–57 base and the most recent years. It should be emphasized that the paucity of information between the periods of systematic release of data by the Chinese State Statistical Bureau (1952–58 and 1977–78), makes empirical calculation for the intervening years even more tenuous. It is necessary to use estimating procedures, such as assumed linear growth rates for intervening years, which frequently results in a smoothed pattern of growth of indexes of both inputs and outputs. Consequently, the analysis of short-run fluctuations in factor productivity should be regarded as more tentative than the long-run trends based on a comparison of 1952–57 with 1977–78.

Finally, setting aside all methodological and numerical disputes, how should one interpret the empirical results emerging from the total factor productivity calculations? In a competitive market framework the residual growth of output that cannot be explained by the growth of inputs has sometimes been taken as a measure of technological change. Of course, numerous refinements in interpretation of such results have been advanced over the past twenty years. But neither the standard nor more sophisticated interpretations may be warranted in the case of the Chinese data. Resource allocation in agriculture does not result from the profit-maximizing behavior of peasants operating in competitive markets but rather reflects a highly constrained process. The government has imposed output and sown area targets on Chinese production units with varying degrees of strictness over time, and inputs and outputs are exchanged at nonequilibrium prices fixed by the state. In short, any index of total factor productivity should be regarded as a starting point for analysis. Do changes in the index reflect technological change or changes in agricultural planning techniques and the structure of incentives? Declining factor productivity with invariant planning and incentive structures clearly would have far different implications for the future of Chinese agricultural growth and the welfare of the Chinese population than would productivity declines reflecting irrational but potentially reversible agriculture production planning practices.

There is no doubt that ill-advised agricultural production planning imposed from above in the years prior to 1978 depressed the growth of agricultural output. When predominantly livestock-raising regions are required to plow up their pastures to grow food grains at yields less than one-tenth the national average, and when some highly productive cropping regions are required to engage in triple-cropping when

there are inadequate supplies of water, labor, fertilizer, and other inputs, there is no question that factor productivity falls (Lardy). But this decline tells us much more about the planning and incentive practices of the 1966–76 period than about the long-term trends in technological change in Chinese agriculture. In my judgment the latter is still largely unknown.

References

Lardy, Nicholas R. "The Prospects for China's Agricultural Growth." Paper presented to a workshop on China's Economic Development and Trade Prospects, Tokyo, June 1979.

Tang, Anthony. *Food and Agriculture in China: Trend and Projections*. Washington, D.C.: International Food Policy Research Institute, 1980.

Chinese Agriculture Development, Production, and Trade: Discussion

James A. Kilpatrick

Surls gives us a useful analysis of the factors that are likely to lead to increased agricultural imports over the next several years. The crucial question, however, will be policymakers' reactions to the various pressures Surls describes. He alludes to this at the end of his section on "Problems of Explaining Trade," when he mentions "uncertainty about . . . past policy changes" and describes current policy changes as "enormous."

Chinese agricultural imports have been expanding since the Great Leap. Nevertheless, comparatively large increases in agricultural imports still can be made from year to year without too great expense compared to the Chinese import bill as a whole. Food import levels have been determined mainly by decisions taken under the pressure of events; they are not the result of far-sighted planning on the basis of information concerning numerous economic variables. Surls is correct in noting that over time the level of food imports has ratcheted up in several discrete steps, notably in 1961, 1973–74, and again in 1977–78. Therefore, instead of a smooth course with small corrections, the Chinese have followed a less predictable path. This means, as Surls observes, that past relationships among observable phenomena do not necessarily yield reliable forecasts of future behavior. It is probably this problem of specification that makes econometric work on the import question difficult, even more than the data problems Surls treats at greater length.

Development Policy

Dernberger focuses specifically on agricultural modernization policies, calling them a "crucial determinant of China's success" in agriculture. He emphasizes that agriculture has been treated as "the foundation of the economy," in principle, since the early 1960s. This has not meant that planners' revealed policy preferences have consistently supported this view, but the slogan has been there. Dernberger catalogues the basic elements of the post-Mao strategy in agriculture, and concludes that the nontechnical aspects of this strategy will, in the long run, determine its success or failure. In particular, the new policies may reduce the peasants' attachment to socialist values and will tend to further increase rural income inequalities. The greatest problem of the post-Mao agricultural policies, Dernberger says, is that they are "seriously challenging the objectives of Mao's socialist revolution." This assumes that there is a trade-off between efficiency and egalitarianism, which is very likely true in most of China's countryside. It should be noted that this trade-off has, for the most part and in most places, been resolved in favor of efficiency since the early 1960s. The Chinese have simply not been able to afford to create Maoist man on their communes, and they have not tried all that hard to do so. Out of necessity, those planners with actual responsibility for agricultural output have had to focus on technical modernization and efficient production.

Productivity

Tang's paper builds on his previous work on productivity. He finds that productivity has declined, and that it has responded to cycles in centrally determined policy. It has increased during periods when efficiency was stressed; and it has declined when the leadership has more actively pursued the political goals that Dernberger identifies as the Maoist side of the revolution. Despite declining productivity, Tang finds that the Chinese have sustained a creditable rate of growth over time. The rea-

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son for this is that they have had to, in order to keep the agricultural constraint from seriously hindering the growth of the economy as a whole. Tang says that agricultural growth is due in large part to "the crucial role played by modern nonfarm-supplied inputs."

These inputs have not raised productivity over the long run, because of the impact of development policies—both the policies themselves and the way they are carried out bureaucratically. The most aggravating factor, perhaps, has been the leadership's preoccupation with what Tang calls "radical experiment." These experiments, designed both to promote egalitarian social goals and to increase production rapidly, have impeded the efforts of the more sober-minded agricultural planners to use conventional inputs efficiently. Tang points out that policy oscillations appear to have become damped over time. The policymakers' freedom of action has been increasingly constrained by the limited number of options available to them to use to increase production, on the one hand, and the need to keep agricultural stagnation from severely reducing economic growth, on the other.

Prospects

The pressure to raise agricultural output is likely to increase for the foreseeable future, for the reasons Surls describes, while the means available to do so will remain limited. These factors, together with the increasing complexity and cost of agricultural programs, should tend to force planners to choose a path of greater efficiency in the use of resources. This, in turn, may well increase the frustration of those who wish to adhere more closely to more egalitarian (or Maoist) policies. The potential for continuing struggle between the two lines that Dernberger describes will create the temptation for policy makers to attempt programs that are motivated by political desires rather than the need to increase productivity to loosen the constraints subsistence agriculture imposes.

One common thread running through all of these papers is the importance in agriculture of policy choices made centrally. The position of China in trade, in incentive policies, or in the efficient use of inputs or other resources, is crucially influenced by a relatively few choices made on the basis of limited information. Unfortunately, China's leaders frequently have seemed impatient with the constraints imposed on them by agriculture, and have elected to pursue large-scale but relatively simple programs in the hope of obtaining quick and dramatic results.

The most prominent current example of the search for panaceas is the mechanization of agriculture. Despite China's relatively high labor/land ratio, mechanization has interested the Chinese for some time and has sparked a good deal of controversy. The Chinese are now among the largest producers and users of tractors in the world. At the end of 1978 they had over half a million conventional tractors (in standard fifteen horsepower units the number would be over twice this large), and were producing tractors at a rate of over 100,000 per year. This is in addition to over a million garden tractors, which are produced at the rate of over 300,000 per year. Foreign visitors to China and, in some cases, the Chinese press, have noted that many of these tractors are not needed—that they are often left to rust or are used for transportation. But tractor production is still increasing, using resources that presumably could be used more efficiently elsewhere.

As the agricultural sector becomes more complex and more dependent on the rest of the economy, this kind of misallocation is increasingly costly. After all is said and done, the success of China's agricultural modernization, and its trade, depends on how much is produced and at what cost. As a practical matter, gains in output must come mainly from such obvious sources as fertilizer, irrigation, and better seeds, because they work, and because the Chinese have not yet exploited them to the fullest extent. (Chemical fertilizer application in 1978, for example, was 89 kilograms per hectare.)

Therefore, input requirements are likely to grow at a rapid rate. For example, production of an additional 100 million tons of grain over current annual levels (a growth rate just under 3% would produce this result in about ten years), would require large increases in inputs that the Chinese apparently have not yet begun to plan for. The last increase of 100 million tons in grain output (attained between about 1965 and 1978) was associated with an increase of over 10 million hectares in irrigated acreage, 7 million tons of chemical fertilizer nutrients and several million tons of organic fertilizer nutrients, and the extension over a

considerable area of high-yielding seed varieties. The next 100 million tons are likely to require similar increases; larger yields require proportionately more water and nutrients than smaller ones. To speak only of fertilizer, an additional 10 million tons or more of chemical fertilizer nutrients are likely to be needed—equal to the production of more than forty of the largest urea plants the Chinese have imported so far. At the moment, there are few indications that the Chinese plan to build new fertilizer plants at the rapid rate needed to sustain the higher levels of output required. The need for investment in fertilizer plants, as well as other inputs, will further constrain planners' choices in the future.

Publications

Books Reviewed

Clawson, Marion. *The Economics of U.S. Nonindustrial Private Forests.* Washington, D.C.: Resources for the Future, Research Paper R-14, 1979, xxiv + 410 pp., $8.95.

The subject of this book is the nonindustrial private forests of the United States. Since only about 1% of them is larger than 500 acres, and since little is said about the larger ones, the book is really concerned with the so-called "small forest owner problem." Part of Clawson's thesis apparently is that there is no such problem.

Clawson defines his audience as "anyone and everyone . . . concerned with these forests." The effects on presentation are unfortunate, because his attempt to make everything understandable to everyone makes the book at least twice as long as necessary. His purpose is "to present as accurate and as informative a description and analysis of the nonindustrial private forests . . . as it is possible to do with the data available." This he largely accomplishes, and this compendium of statistical and descriptive material makes the book worthwhile. An appendix of sixty-one tables provides detailed statistical background.

But Clawson is not content with description, and it is in his analysis that problems arise. He starts with the statement that "it will be necessary to refute or to correct extensive misconceptions, amounting in some cases almost to myths, about these forests," and says he "will show that such ideas are, in the main, exaggerated or wrong." To anyone who has been involved with nonindustrial forest programs and policies for very long, much of this smacks of setting up straw men for the purpose of demolishing them.

Considerable space is devoted to showing that when the nonindustrial forests are compared with those in industrial ownership on a state-by-state basis, they appear quite similar in productivity, growing stock per acre, and proportional annual yield. Clawson has presented this same idea earlier. He is right that one can only determine whether there is a problem by comparing these nonindustrial forests with something, and there is no absolute standard for this purpose. But his disaggregation of the national data to a state basis sweeps some things under the rug.

The comparison includes only states with substantial industrial forest ownership. This excludes Kansas, for example, which makes the industrial/nonindustrial comparison come out closer because 55% of Kansas' forests are on very poor sites compared to 27% in the nation as a whole. But these low-productivity woodlands may seem pretty important to Kansans, whose state is 97% open.

The weakest part of Clawson's analysis is his attempt to use the neoclassical market model to explain the buildup of growing stock during the past three decades. Most forest economists feel that stumpage supply is largely a stock situation. To the extent that these nonindustrial owners respond to price signals, it is in terms of selling what is already grown and standing in their woods. Any response in the form of management practices aimed at future harvests is hard to document. Where the land has alternative uses, these owners do respond to price changes. But this response has been away from forest use and into soybeans, improved pasture, or housing developments. It has continued despite rising timber prices.

The movement of land into forest and the buildup of growing stock in existing forests has been influenced heavily by institutional factors. Tree planting has been a major part of extension and state forestry programs. Subsidy programs have had an impact. Public fire prevention and control have become increasingly effective. The amount of wood cut for fuel fell off drastically after World War II, and the amount used for farm maintenance has declined with the decrease in the number of farms. As Clawson notes, much of the growing stock consisted of inferior species and qualities for which there were no markets. The trees that were left in the woodlots continued to grow and add to the standing volume. The impact of these factors on the growing stock would have been the same regardless of what happened to timber prices. So Clawson's supply models, which show an increase in current annual growth with an increase in stumpage prices ten or twenty years earlier, may be just a nonsense correlation.

A rather short chapter discusses the managerial problems of the small forest owners. The treatment seems adequate for this kind of book, although it makes little reference to the voluminous literature on this subject. The same cannot be said for the last chapter, which deals with public forestry programs. The treatment here is totally inadequate for a book of these pretensions. The Cooperative Forest Management program receives one sentence, and the Cooperative Extension Service is mentioned only once. It would have been much more informative if Clawson had analyzed the successes and failures of these public programs at greater length, and had devoted less of his space to the detailed statistical analyses of earlier chapters.

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Book Review Editor's Note:

The following review differs from other articles normally appearing in this section of the *Journal.* It

is based on the government publication *Structure Issues of American Agriculture*. This report is comprised of essays from a large number of agricultural economists in government service. It has been distributed widely in the profession and received much attention because of its policy relevance.

B. F. Stanton's review, with inputs from R. N. Boisvert, K. L. Robinson, and W. G. Tomek, comments on this effort in a more substantial manner than is possible in the space normally allocated to an individual review.

H. H. Stoevener

ESCS Staff. *Structure Issues of American Agriculture*. Washington, D.C.: U.S. Government Printing Office, USDA Agr. Econ. Rep. 438, Nov. 1979, 305 pp.

In 1979, structure emerged again as a key word in the political economy of agriculture. This large paperback, commissioned rather hurriedly by the Secretary of Agriculture, contains a collection of essays written by ESCS staff to foster discussion and debate on farm structure issues. Many of the authors are well-known in the profession. The report has been widely advertised by the Secretary and broadly distributed. Most agricultural economists in the United States have a copy or ready access to one.

Why all the renewed interest in structure? Certainly part of the explanation is political. But the underlying reasons have more substance. There is growing interest and concern about ownership and control of natural resources—especially productive agricultural land and water. This concern extends well beyond the bounds of production agriculture. Tax laws encourage the accumulation of wealth by commercial farmers. Land prices in the 1970s increased faster than the rate of inflation. The divergence in wealth and income between a thirty-cow dairy farm in Wisconsin and a 1,000 acre wheat farm in Kansas is much more obvious now than ten years ago, even though both are one man, family businesses. There is a back-to-the-land movement among a number of young people from middle income families. There is also a continuing concern for the rural poor who often live beyond the reach of public services on unproductive land and with meager housing. Farmers, leaders in the rest of the food industry, government officials, and the general public feel they have a stake in the way agriculture is organized.

The book and the associated discussion about structure already have accomplished a number of things. (*a*) The book has provided a basic core of information around which national discussion of structure issues can be centered. (*b*) It has summarized current thinking and implicit priorities of USDA economists on these policy issues. (*c*) The overall effort has rekindled interest in the agricultural economics profession to seek answers to the many questions related to structure that remain unanswered. (*d*) It has even prodded some land grant administrators into giving some priority to public policy research and extension.

The book itself considers structure issues in six major sections. The space accorded to each says something about both politics and priorities. J. B. Penn, Deputy Administrator for Economics, ESCS, provides the overview. His is a balanced statement emphasizing commercial agriculture and the dynamic forces which continually lead to change. Babb's two analytical statements on causes and consequences of structural change are particularly useful. Brewster provides historical perspective on national concerns with structure over the years and the changing definitions of family farms. The essays on farm production issues predictably center on land, labor, capital, technology, and management. This section also provides a brief review of what we know and do not know about economies of size, barriers to exit and entry, and alternative forms of business organization.

The middle section, entitled "Public Policies," is also directed primarily toward commercial agriculture. General tax policy, land and water use, price and income policy, environmental regulation, energy, and transportation are all considered briefly. Each of these essays points to ways in which current policy has or may affect farm structure. Very little effort was made to differentiate between what can be accomplished directly through agricultural legislation and associated policy instruments, in contrast to working with more complex problems of general legislation where agriculture is a small part of the political picture. Setting limits on government payments to individual farmers is one thing; changing the rules for individual income taxes is quite another.

The last three sections—"Marketing," "Rural America," and the "Experience of Others"—were assigned less than 90 of the 305 pages. These sections recognize that structure issues involve much more than commercial farming. Input supply, manufacturing and food retailing, the role for cooperatives, and market mechanisms for price determination were emphasized in the marketing section. Structure, conduct, and performance have received substantial attention by economists concerned with the sectors from which farmers buy and to whom they sell. Concerns about thin markets, formula trading, and forward selling activities were recognized appropriately. An examination of the bargaining position of farmers when they buy in factor markets and sell in product markets was not given much attention.

The twenty pages accorded "Rural America" must say something about the low priority accorded within USDA and nationally to part-time farming, rural poverty, and the impact of changing structure on rural communities. Currently two-thirds of the units counted as farms in the national statistics and

more than half of the farm population are located on farms that sell less than $20,000 of farm products. Most of the reduction in farm numbers in recent years has come from these smaller units, and almost none from those with at least one full-time person engaged in farming.

Prices approximately doubled between 1966 and 1978. If one reconstructs the size distribution of farms in 1966 using a 1978 base, one can examine recent changes in that size distribution over twelve years more clearly (table 1). The shift to larger farms is evident but much less dramatic than is frequently recognized when changing price levels are not considered explicitly.

Living on the farms selling less than $20,000 of farm products are a diversity of people with a wide range of interests and problems. This is an area where our factual knowledge about employment, incomes, and opportunities is clearly deficient. Many in this category are part-time operators who prefer to live in the country and combine off-farm employment with some farm production. Some are truly disadvantaged, rural poor, living on unproductive farms with few alternatives. The four essays in this section point to some of the problems and issues, but they provide only a small beginning relative to the size and importance of the problems involved and the difficulty of finding workable solutions.

The preceding paragraphs have tried to provide a glimpse of the materials covered in this generally calm and carefully correct collection of papers. The book brings together in summary form a useful overview of our current state of knowledge about structure issues in their many dimensions. Agricultural economics as a profession has been well served by this initiative.

The very breadth and balance attempted in the coverage of issues leaves a certain sense of inadequacy as well. If one really wants to stir up debate, one needs to concentrate on a few high priority topics, offer some proposals and examine the likely consequences. In many respects this is the challenge that was not faced in this book. But it is clearly left open to readers of this *Journal* to pursue.

Substantial study of a limited number of issues in depth could yield important dividends. Consider, for example, three quite different topics, all related to farm size.

(*a*) *Tax policy.* Observation suggests that tax incentives have been one of the strongest forces leading to increased farm size during the last decade. Can we document the impact of investment credit, capital gains treatment, and the cash reporting option on individual farm growth? Because income tax legislation applies to individuals and businesses generally, what workable options are open to reduce inequities, if they exist?

(*b*) *Payments limitations.* Agricultural commodity programs and disaster loans and payments have differential effects on farms by regions and sizes of units. What are the impacts of current legislation on farms of different sizes and how might differential limits on payments be established?

(*c*) *Statistics on farm numbers and incomes.* Classification of farms into more meaningful groups has not been made. The commercial sector is not identified as such. Sources and levels of income for people living on "farms" where small amounts of products are sold are not known with any degree of confidence. Any efforts to meet the needs of these rural people needs a stronger factual base.

Table 1. Number of Farms by Values of Sales (United States, 1966 and 1978 in Constant Dollars)

Gross Farm Sales	1966	1966 (in 1978 Dollars)	1978
	(thousands of farms)		
Under $2,500	1,389	1,389	916
2,500–4,999	457		279
5,000–9,999	476	457	281
10,000–19,999	445	476	296
Subtotal	(2,767)	(2,322)	(1,772)
20,000–39,000	304	445	323
40,000–99,999	143	340[a]	390
100,000–199,999	43	107	124
200,000 and over		43	63
Subtotal	(490)	(935)	(900)
Total	3,257	3,257	2,672
C.P.I. (1967 = 100)	97.2		195.4

Source: ESCS, *Farm Income Statistics*, USDA Statistical Bulletin 627, Oct. 1979.

[a] All of the farms in the original $20,000–$39,999 class plus 25% of those in the next larger size group.

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Hannesson, Rognvaldur. ***Economics of Fisheries: An Introduction.*** **Oslo, Norway: Universitetsforlaget, 1979, 156 pp., $18.00 (distributed in the United States by Columbia University Press, New York).**

Hannesson's *Economics of Fisheries* joins the small fisheries economics literature that already includes the recent books by Anderson, Bell, and Clark. Clark's book is confined primarily to the development of mathematical models applicable to living resource exploitation, and Bell's is a far larger work with chapters on aquaculture, recreational fishing, and environmental deterioration. Hannesson's new book has most in common with Anderson's. Both concentrate on the application of standard economic models to commercial fishing. The *Economics of Fisheries* consists of a collection and exposition of theoretical models of fisheries economics, spiced with some empirical examples and numerical illustrations. The first chapter introduces the biolog-

ical basis for much of the theory, explaining concepts from the field of population dynamics such as surplus growth, instantaneous mortality rate, fishing effort, and sustainable yield. Chapter 2 develops the notion of bionomic equilibrium, the state in which both biological and economic relationships are in equilibrium. The bionomic equilibrium is compared to the profit-maximizing yield and effort levels, and the "stock externalities" occurring in a free access fishery are shown to cause a misallocation of resources.

In chapters 3 through 6, Hannesson explains the fishery supply curve and factor rents, develops the concepts of welfare economics necessary to demonstrate the inefficiency of free access, explores the efficiency consequences of sole ownership of fish stocks, and briefly considers the use of taxes and other public policies for managing fisheries. The simple economic model used in these chapters relies upon a surplus yield model of the fish stock, a total cost function, and a revenue function. Constant costs and increasing costs of effort, as well as constant and variable price of output, are discussed thoroughly. The discussion relies primarily on graphs and algebra, but occasionally uses more sophisticated mathematics.

The book concludes with three excellent chapters illustrating the bioeconomic theory with (*a*) a quadratic yield curve, (*b*) a Beverton and Holt-type age-structured model, and (*c*) a Ricker recruitment model. Each of these biological models has important applications in the fisheries literature. Hannesson places each in an economic context and provides numerical examples to highlight specific problems. Because they capably demonstrate how economic models can be linked to biological models, these three chapters provide perhaps the most important and useful contributions of the book.

A blemish in the book's generally thorough coverage of theoretical tools is in the treatment of production costs. With free competition and no fishery regulations, one can assume as Hannesson does, that costs are a function solely of fishing effort. But when the free access fishery is limited by an annual quota, an increasing price of fish will attract additional firms. The annual catch and annual fishing effort will be split among more and more firms as the fleet grows. If there are any fixed costs of entry, the cost per effort will increase with fleet size while the level of effort remains constant. Thus, the production costs cannot be treated as a function of effort if the full range of management devices is to be investigated. Leaving the reader to conclude that control over fishing effort permits control over costs of production, Hannesson provides neither an explanation of the over-capitalization found in fisheries under quota management nor a basis for the use of limited access programs. As a result, the brief discussion of taxation, license limitation, and competitive bidding for fishing licenses in chapter 6 provides no clear framework for economic evaluation of the various management methods.

In addition to this weakness in theory development, the book has some weaknesses in construction and coverage which raise possible difficulties for classroom use. First, the level of economic and mathematical ability required is uneven. To follow the discussion of fishing effort (pp. 17–18) and factor rents (pp. 45–48), for instance, the reader should have a knowledge of microeconomics at the intermediate level. But with this background, the reader will find unnecessary much of the introductory lecture on welfare theory in chapter 4. Similarly, the graphical development of the fishery supply curve in chapter 3 probably will try the patience of the reader capable of handling the Hamiltonian function and Pontryagin maximum principle utilized in the previous chapter's discussion of discounting. A second weakness is the author's frequent tendency to interrupt the smooth development of topics by inserting excursions on subjects covered in greater detail elsewhere in the book.

Finally, while the author intentionally has focused on the development of general theory, the discussion of fishery management or fishery economics cannot proceed far without reference to the institutional and organizational context in which management policy is formed. Nor can the student of fisheries afford to ignore, as Hannesson does, the noncommercial uses of fishery resources. Thus the book does not cover the whole of its subject area. Despite the weaknesses and shortcomings noted here, however, the book is well worth acquiring. The concluding three chapters should be especially valuable to students specializing in resource economics.

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References

Anderson, Lee G. *The Economics of Fisheries Management.* Baltimore, Md.: Johns Hopkins University Press, 1977.

Bell, Frederick W. *Food from the Sea: The Economics and Politics of Ocean Fisheries.* Boulder, Colo.: Westview Press, 1978.

Clark, Colin W. *Mathematical Bioeconomics: The Optimal Management of Renewable Resources.* New York: John Wiley & Sons, 1976.

Howe, Charles W. *Natural Resource Economics: Issues, Analysis and Policy.* New York: John Wiley & Sons, 1979, xxviii + 350 pp., $19.95.

Howe claims to have developed a textbook which "integrates the field of natural resource economics for the first time" (p. vii). The book reflects a significant contribution toward this laudable goal.

Yet, total integration was not completed and perhaps should not be expected in one book designed for a one semester course.

The book rests heavily on macroeconomics with a complement of capital theory. The Malthusian and Ricardian growth models are developed in a precise manner in the first seven (of sixteen) chapters, drawing heavily on the early work by Barnett and Morse, but supplemented with many original insights. The author's major premise that a simple macromodel can be used to isolate the major issues and yield correct answers (p. 62) may be subject to question, however (see Smith and Krutilla).

The first three chapters are devoted to a definition of issues, establishment of a historical perspective, and an empirical survey of natural resource commodities and stocks. Howe is sensitive to the need to clarify terms (e.g., what is a "resource base" as compared to a "resource" and a "reserve"?), reflecting an apparent predilection toward communication with other disciplines.

The reader is first introduced to models showing gross national product (GNP) as a function of natural resource commodities, labor, and (manmade) capital stock in chapter 2. The very important point that natural resource commodities (e.g., water for irrigation) are produced from natural resource *in situ* stocks (e.g., water in a natural source) through the interplay of socioeconomic forces is made early. The relationship between natural resource commodities and *in situ* stocks, and the interconnection of both with the GNP, is then addressed through gradual introduction of growth and technological change conditions in chapters 4 and 5. Howe does a commendable job of isolating the effects of alternative assumptions about scale elasticity in the resource transformation function.

The relation between remaining resource stocks and the costs of producing natural resource commodities is illuminated in chapter 4. This contribution sets the stage to provide some long needed clarity as regards the rent concept. We then learn later in chapter 5 that optimal resource use over time implies that the price of the resource commodity must be equal to the sum of the marginal loss of environmental services, the marginal cost of resource conversion, and the scarcity rent. Howe has been careful to include concern for environmental costs. He also is willing to admit (chapter 5) that a competitive market may fail to allocate natural resources in the socially desired manner over time; however, a felt need to use the market institution is an underlying theme of the entire book.

Chapter 6 is devoted to a review of efforts to measure natural resource scarcity through various empirical indicators. Factors working to reduce the effects of resource scarcity are reviewed in chapter 7. Issues regarding intertemporal resource allocation, including selection of a discount factor, are discussed in chapter 8.

Chapters 9, 10, and 11 review problems peculiar to the energy, mineral, and forestry resources. Statistics are provided on use and availability; models of exploration and exploitation are presented. Chapter 12, on common property problems, provides the absolute minimum in knowledge required to consider the fishery, water, and natural area-ecosystem resources in chapters 13–15. Interestingly, Howe has chosen to equate "adverse interactions" with "externalities" (p. 241), precluding the possibility of a mutually beneficial interdependency being considered an externality (and a problem) as well. Also, if one followed the Howe book religiously through this section, the topics relating to "public goods," liability rules, decreasing cost industries, and much of the literature on the means to reduce the effects of market failure would not be introduced as the subject matter of natural resource economics. However, Howe does refer the reader to "the many good elementary books" on the economics of environmental management (p. 252). Fortunately, if one heeded his advice, most of this literature also would be taught (appropriately) as natural resource economics.

A major shortcoming of the book is the lack of a cogent attempt to define the boundaries of institutional analysis. The book is traditional, in that institutions are exogenous to the system. This may be especially bothersome to those who have recognized that institutions probably are best thought of as endogenous (Kelso). The traditional approach also tends to treat a natural resource as capital in the production process. While Howe makes some progress here, there is still little new insight into how natural systems can be better represented in a production function. More attention to the agricultural economics literature may have helped (e.g., crop response modeling, pest models, etc). Howe concludes (chapter 16) with an excellent summary of the major issues for natural resource policy.

The Howe book is a valuable addition to the recently started flow of textbooks in the area. With the above caveats, it can be used in a first course for graduate students who are well grounded in quantitative methods and intermediate micro and macro theory. Howe also has recommended its use for upper division undergraduates and noneconomics majors. This could be feasible only with sufficient embellishment by the instructor to clarify and illuminate lectures. The book is well written, with both algebraic examples and "intuitive" discussion used freely to illustrate difficult concepts.

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References

Barnett, Harold, and Chandler Morse. *Scarcity and Growth: The Economics of Natural Resource Availability*. Baltimore, Md.: Johns Hopkins University Press, 1963.

Kelso, M. M. "Natural Resource Economics: The Upsetting Discipline." *Amer. J. Agr. Econ.* 59 (1977):814–23.

Smith, V. K., and J. V. Krutilla. "Resource and Environmental Constraints to Growth." *Amer. J. Agr. Econ.* 61 (1979):395–408.

Knapp, Joseph P. *Edwin G. Nourse—Economist for the People*. Danville, Ill.: Interstate Publishers, 1979, 544 pp., $11.95.

Not long ago news magazines asked, "Where have the [national] heroes gone?" They puzzled over whether heroes are nonexistent or merely unrecognized and implied regret over lukewarmness toward them.

Biographer Joseph Knapp asks the hero toga for Edwin G. Nourse, a pioneer agricultural economist who died in 1974. Knapp sees Nourse, however, as a hero not just of agricultural economics, but broadly, of the social sciences made relevant to public affairs. Knapp senses a burden of persuasion arising less from doubt than from an unfamiliarity that he sets out to correct.

Agricultural economists remember Nourse as an early cooperative theorist and an original AAEA Fellow. Less known is that as early as 1916, during a three-year tenure at the University of Arkansas, he compiled a text titled simply *Agricultural Economics* (subtitle, *A Selection of Materials in Which Economic Principles are Applied to the Practice of Agriculture*); that he was the first chairman of a separate department of agricultural economics at Iowa State College; that as a young professor at the University of South Dakota in 1910 he suggested that the state's wheat farmers market cooperatively, and later when at Iowa State he headed a seventeen-man study of West Coast farmer cooperatives; and that he pioneered also in giving status and structure to research in agricultural economics as a member of a committee of the Social Science Research Council, newly established in 1925, where he was "chief proponent" for the Council's making grants "to improve the quality of social science research in agriculture" (p. 113).

Likewise, in his lifelong role of being first in the newest, Nourse left Iowa State after the 1922–23 school year to join the new Institute of Economics of what was to become The Brookings Institution, and from that position he established "liaison" with the just-founded (1924) Brookings Graduate School of Economics and Government. While at the Institute, Nourse published the pathbreaking *Legal Status of Agricultural Cooperation*, and helped establish the American Institute of Cooperation. From the vantage point of the Institute and as a confidant of Henry Wallace, M. L. Wilson, Chester Davis, Howard Tolley, and other leaders, Nourse was in the mainstream of the emerging farm policy, beginning with the Farm Board and continuing through the early Agricultural Adjustment Administration. In 1937, he joined with Joseph Davis and John D. Black in publishing the historic *Three Years of the Agricultural Adjustment Administration.*

Although he periodically dipped into agricultural policy, co-authoring the postwar "Turning the Searchlight on Farm Policy" and never losing his interest in agricultural cooperation, Edwin Nourse turned at mid-career almost exclusively to national economic policy. In 1944, was published his *Price Making in a Democracy,* a title that accurately characterizes his institutional orientation. In 1942, he was president of the American Economic Association (he had been American Farm Economic Association president in 1924) and in 1942–45 was chairman of the Social Science Research Council.

Nourse's growing distinction in general economic issues and policy culminated in his being named chairman—first, again—of the Council of Economic Advisors, the presidential advisory agency brought into being by the Employment Act of 1946. His vicissitudes as Council chairman and his later career will not be annotated here.

Worth noting, however, regarding Nourse's entire career is that he was not an agricultural economist who ventured outside his discipline. Instead, he was a scholar schooled in economics, history, political science, and sociology, whose interests extended to agriculture. Urbane and articulate, he did not fit the stereotype of the agricultural economist. Wrote Joseph Spengler, "I was impressed when I saw Dr. Nourse sculpting for he was the first economist so gifted as to my knowledge. I was struck also by how nicely dressed he was, bow-tie and all, for that did not associate with cooperative marketing and agriculture in my then knowledge" (Spengler to Knapp, 18 June 1973, p. 149).

Nourse's interest in cooperatives was consistent with his self-categorization as an institutional economist.

> I stand for the institutional position. . . . I am interested in the institutions which we have set up as a framework of our economy which we have built up out of ideologies and psychological reactions. This is all tinged with a heavy pragmatic tone. . . . (Nourse to Knapp, p. 469)

Aptly revealing of the Nourse mindset was the title of a 1958 article, "Intellectualism on the Economic Front." Edwin Nourse urged leaders of business, labor, and government to be public spirited intellectuals. He was not happy with organized power groups and hoped their leaders would exhibit "economic 'savvy' and powers of discipline of forbearance" (p. 275). On another occasion he was more hopeful, as he saw new economic thinking as keynoted by "recurring emphasis on 'management' and social responsibility" (1958 *Yearbook of the National Council for the Social Studies*, p. 370).

Joseph Knapp's account is strongest in delineating his hero's conflicts and philosophies, weakest in personal narrative. If a biographer is expected to

reflect, self-effacingly, the biographee's talents rather than his own, Knapp succeeds well. His chronicle of the life of Edwin Nourse has the further merit of constituting a commentary on the fledgling discipline—and profession—of agricultural economics.

Knapp's last recounting is of Nourse's "unfinished symphony" (Nourse's prophetic term, for it was not completed), which, says Knapp, promised "rich insights into the applicability of social science to the major problems of our times" (p. 491). Knapp gives the gist of the "symphony" as his Appendix B. Certain it is that our times can use counsel from the kind of social science intellectual that Edwin Nourse was.

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Socolofsky, Homer E. *Landlord William Scully*. Lawrence: The Regents Press of Kansas, 1979, xiii + 182 pp., $15.00.

In his prefatory remarks the author declares that the "intent of this book is to narrate for the general reader, as carefully and completely as possible, the life of William Scully." If this were all that the author had accomplished, it is doubtful that the book would be of academic interest to agricultural economists. Even though he disclaims any intent to do so, Socolofsky has woven into his account of the life of William Scully sufficient information about the Irish land tenure system and the development of the Scully leases on his U.S. property that serious students of land economics will find this book rewarding as well as entertaining.

The life of William Scully, a scion of the landed gentry in Ireland, from his birth in 1821 to his death in 1906 spans a period of enormous change in the institutions and attitudes that govern man's relationship to land. Scully is portrayed as an active participant in this process of change, at times resisting it with all his power, and at other times incurring the ill will of his contemporaries because he was too early and too impatient with his own innovations.

Through all this Socolofsky manages to present the evidence available as even-handedly as possible. He refrains admirably from filling in with surmises and judgments where evidence is lacking. Neither does he attempt an evaluation of the life of William Scully or to pass personal judgment on him. The evidence is too fragmentary and already too much tainted by value judgments in the accounts drawn from available media sources. Therefore, the reader is free to draw his own conclusions.

Much of what William Scully achieved, whether for good or for evil, was the result of his own strong will and determination. How many of us would, at thirty years of age, leave a comfortable existence and place a fortune (then) of $85,000 at risk in an alien land? On the other hand, should Scully be credited with a peculiar wisdom in selecting what is today some of the most productive and valuable farmland in the entire U.S. midwest? After all, this was almost the only choice available to him in 1852 prior to the technological developments that later permitted this swamp land to be drained and used intensively in grain production.

Scully's dealing with his tenants ran the gamut from that of a harsh, unfeeling rent-collector, to an advocate of progressive farming who made voluntary rent abatements in years of poor crops and low incomes. Tracing, through Socolofsky's account, the prudence, care, conservatism, and foresight, together with a stubborn insistence on his legal rights, reveals how the purposeful behavior of William Scully, combined with the fortuitous events of his time, resulted in his accumulation of an estate in U.S. farmland that aggregated at one time about 225,000 acres.

Those who would gain a useful historical perspective on policy questions being voiced today about alien ownership of U.S. farmland and about concentration of farmland ownership will find this book enlightening. Unfortunately, they will also find it a bit frustrating in that the author did not choose to write a more comprehensive volume that would have included, among other things, a fuller exposition of the English land tenure system that formed the context for Scully's problems with his Irish tenants. And one could wish for a more complete coverage of the American taxing system as it may have and is now impacting on the Scully estate.

It is quite clear that throughout his life William Scully was strongly motivated by his own self-interest and that of his immediate heirs. Whether this pursuit of his own self-interest also served the interests of society, à la Adam Smith, is an open question.

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Walinsky, Louis J., ed. *Agrarian Reform as Unfinished Business: The Selected Papers of Wolf Ladejinsky*. New York: Oxford University Press, 1977, xi + 601 pp., $22.00, $10.95 paper.

Wolf Ladejinsky was a brilliant observer of Asian rural life whose articles, reports, and dispatches were colored by an obsessional fear of communism. His early articles were rather workmanlike summaries of agricultural conditions produced without the benefit of firsthand knowledge. Although they lacked the vivacity of his later field studies, they won him a reputation as an expert in land reform.

His postwar studies seemed to come to life, perhaps as a result of his contact with the lives of the Asian peasant. We can readily see why they won Ladejinsky the support of General MacArthur, who had himself earlier come to recognize the political

necessity of land reform. In part inspired by Ladejinsky, McArthur was convinced that enlightened reform could draw support away from the communists.

Fresh from his initial success in Japan, Ladejinsky was sent to Taiwan and to Szechwan, the last remaining nationalist province on the Chinese mainland. Although reform came too late in Szechwan, on Taiwan a newly arrived force which was free from undue pressure from landlords was able to reap political profit through land reform. During a short trip to Kashmir, Ladejinsky was pleased to discover a roughly similar instance in which the Muslim government was able to expropriate the land from mostly Hindu landlords. In the rest of the Asian continent, the will for land reform was lacking.

National elites whose wealth was mostly based upon land holdings were reluctant to see it redistributed or even to lessen their earnings from the land. Ladejinsky called upon the Ford Foundation to use its resources to subtly prod the Indian government in the right direction before it was too late. But to little avail.

It was already too late in Vietnam, his next assignment. The Viet Minh had successfully preempted the issue of land reform. Reading Ladejinsky's reports from as early as 1955, one can see that the war was already lost. Nonetheless, until 1961, Ladejinsky doggedly espoused the cause of his employer, President Diem.

I have the feeling that the Viet Nam period may have been a turning point for Ladejinsky. Previously, he seemed to exhibit an attitude as if through land reform one could keep "the sheep alive and the wolves happy" (p. 259). Faced with the bloody conflict in Viet Nam, he seemed to plead for effective land reform only as a holding action against the Viet Minh.

The Viet Nam experience might have prepared him to expect the worst in India, but it did not. Afterwards, in his employment with the Ford Foundation and the World Bank, he repeated his fears of imminent communist revolution, but without the same conviction. It seemed to him as if poverty in India was more conducive to patience than revolution (pp. 452, 528–29).

I believe that the reason for Ladejinsky's vision of the future can be understood in terms of his attitude toward peasants. He was undoubtedly a superb listener when he met them. He respected their innate abilities, but the movers and shakers of the world were the elites (pp. 197, 395). To Ladejinsky, Viet Minh were astute politicians who could effectively manipulate the people; the Indian left was to be held up for ridicule. Consequently, he was prepared to see India embark on a process of capital accumulation which would disposses workers from the land; but he warned that the utmost caution was required. Accordingly, he attempted to teach the naive Green Revolutionaries not to make a fetish of new technology.

His brilliant field notes on India were an attempt to bring the technocrats and politicians into contact with conditions in the village. This role exposed the fundamental weakness of Ladejinsky's vision of land reform. His verdict of Indian land reform could be extended to Japan and Taiwan as well: ". . . the people in whose behalf the reforms were designed . . . are the *objects* of reforms, but never the *means* of helping formulate and carry them out" (p. 401; italics in original).

To discover what land reform by the people might mean, one must turn from Ladejinsky to other sources. William Hinton's *Fanshen*, the story of a Northern Chinese village's land reform, for example, illustrated what such land reform would mean.

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Reference

Hinton, William. *Fanshen*. New York: Vintage Press, 1966.

Waterbury, John. *Hydropolitics of the Nile Valley*. Syracuse, N.Y.: Syracuse University Press, 1979, xii + 301 pp., $20.00.

The Nile is the lifeblood of two countries, Egypt and the Sudan. Egypt, with its dense population confined to the irrigated lands along the Nile, and the Sudan, with a small population but vast potential for irrigation development, are locked into total development of the river. Both countries currently rely heavily on the Nile for irrigation and each plans expansion of water use to meet the needs of rising expectations and population growth. This book expertly outlines the plans and problems that must be faced in such development. Egypt, being a downstream user, long has been aware of its insecurity with respect to water supply should the Sudan lay claim to larger quantities of water. Various schemes have been proposed to alter and increase the flow of the Nile, all of which lie within the Sudan. As long as Great Britain controlled the Sudan and maintained a presence in Egypt, planning for projects to increase the flow of the Nile moved fairly smoothly, although funding was short and progress slow.

With the coming of independence from Colonial rule, some of the stability and cooperation between the two countries has slipped away. No longer is Egypt the stronger voice in development of Nile water supplies. Sudan is beginning to assert its claims on the Nile. Nor is this all; other countries at the head waters are beginning to show an interest in the use of the head water of the Nile. Kenya, Uganda, Zaire, and especially Ethiopia are planning projects for irrigation within their own boundaries.

Each of these schemes has important implications for Egypt because any upstream development ultimately must be felt downstream, as this water no longer flows to the Mediterranean. Egypt, with 40 million people and a high birth rate, needs to expand its irrigated base as well as develop industry to employ its people. So its future demands on the river will be great if the welfare of the country is to rise.

John Waterbury has done a masterful job of detailing the problems faced by two emerging national states as they struggle to gain control of and manage a scarce transnational resource with each insisting upon its sovereign rights to utilize the resource as it sees fit.

The book is divided into eight chapters with an introduction and a conclusion. The first chapter lays out the development that has taken place on the river system. Chapter 2 deals with the political and economic realities that face the Sudan and Egypt. Chapter 3 describes the water supply of the river and the struggle of each nation to develop security to its share of the Nile's flow. Chapter 4 delves into the political machination of the leading powers of the world in developing the Nile, leading up to the development of the High Dam at Aswan.

The effects of the High Dam on the Nile River in Egypt is described in chapter 5. The High Dam, that was to provide new prosperity to Egypt and allow it to control its destiny by capturing the Nile, provides a fascinating study. The effects of the High Dam on water use and development in Egypt and the problems and promise created by the dam follow in chapter 6. Sudan's potential for large-scale agricultural development and the threat to Egypt's need to expand use of the waters of the Nile is detailed in chapter 7. Chapter 8 outlines the potential shortage (and conflict) that will exist on the Nile by 1985–90 if both the Sudan and Egypt proceed with plans to develop and use the water.

Egypt has little choice but to expand use of the water because of its population growth. The Sudan promises to be a rich agricultural exporter in an increasingly shortage-stricken world. Oil funds from the oil kingdoms are beginning to move development in the Sudan, so the stage is set for a classic struggle in which each nation has a crucial stake.

Waterbury suggests four measures which could avoid a major crisis in the use and development of the waters of the Nile: (*a*) The Sudan could freeze its irrigated agricultural base at current levels; (*b*) Egypt could put its efforts into industrial development and delegate basic agricultural production to the Sudan. The two countries could trade industrial goods and agricultural products; (*c*) Both countries could make breakthroughs in efficient use of water in agriculture. And, (*d*) all projects on the upper Nile could be completed in fifteen years with no other country making demands on Nile water. But he concludes that it is unlikely that any of the four are remotely probable.

Waterbury stresses the fact that "Economic and Political Benefit/Cost analysis are not separate fields, and it is because of their interdependence that instrumentalities must be devised to link the technocrat to the politician." Egypt's High Aswan Dam is a case in point. The geo-political benefit of having the key to assured water supply within Egypt's borders, was of overriding importance in creating the Dam.

Waterbury points out that economists and others who work in the field of resource management in the contemporary world must be able to incorporate the political aspects as well as the technical when evaluating resource development projects. This book will be valuable to economists and others who must deal with the relationship between political policy and technological resource development and management.

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Articles

Notes

Articles

Behavior and Productivity Implications of Institutional and Project Funding of Research

Maury E. Bredahl, W. Keith Bryant, and Vernon W. Ruttan

A behavioral model of a research scientist is utilized to develop the characteristics of the demand for institutional (IR) and project research (PR) funds. The demand analysis implies a trade-off between the allocative and productive efficiency of IR funding and the research output mix of PR funding. The model is used to evaluate the formula and competitive grant funding of U.S. agricultural research. We conclude that national research policy should be cast in terms of the relative mix of the two systems of support, not in the absolute merits of either system.

Key words: agricultural research, allocative efficiency, demand for research funds, research-funding policy.

In this paper, we analyze the implications of two alternative research-funding schemes. The first, institutional research (IR) support systems, provides funds to support the research program of a particular research institution. Typically, the funds are not targeted to research areas. Rather, the selection of research areas is made by the administrators of the research institution or individual researchers. The second, project research (PR) grant system, provides support through project grants to individual scientists or research teams. The allocation of research effort typically is determined by the granting agency.

Examples of institutional support for research are numerous. IR was the traditional instrument employed to support federal and state mission-oriented research in the fields of defense, agriculture, natural resource exploration, industrial standards, and related areas prior to World War II (Dupree, Stein). The program of federal support for agricultural experiment stations on a formula basis is a prototype of the institutional research system.[1]

In the private sector, the Ford Foundation has provided institutional support for the research program of Resources for the Future since the early 1950s. Institutional grants were also made to Social Science Research Council to enable the Council to operate the Foreign Area Fellowship Program—a program of project grants. The U.S. Agency for International Development (USAID) provides institutional grants in support of the research programs of the international agricultural research centers which are part of the Consultative Group on International Agricultural Research.

The competitive grant program of the National Science Foundation, in which grant requests are received from individual scientists or research teams and evaluated by peer panels, is a prototype of the project research system. Most of the major foundations and a number of federal agencies operate project research grant programs in addition to IR programs. The project research grant mechanism emerged as a major instrument for linking academic research with mission-oriented federal agencies in the late 1940s and early 1950s (Stein).

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The authors have benefited from comments on an earlier draft of this paper by Emerson Babb, Robert Evenson, Walter Fishel, Edward Foster, Don Hadwiger, R. J. Hildreth, Keith Huston, Yoav Kislev, Michael Lea, Willis Peterson, Jean Robinson, Roland Robinson, Theodore W. Schultz, and Burt Sundquist.

[1] Funds allocated to the states under the Hatch Act, except for funds reserved for cooperative regional research efforts, are allocated to the state agricultural experiment stations by a formula based on the number of farms and the size of the rural population in each state. The several sources of federal funds for state agricultural research are identified in the latest annual report of the USDA Cooperative State Research Service. Factors affecting the support for state agricultural experiment stations have been analyzed by Huffman and Miranowski, Peterson (1969), Heady (1961, 1962), and Dalrymple (1962).

Each of the two research management schemes has strengths and weaknesses. The system constraints and the reward systems are very different under IR and PR research management. The next section of this paper presents an analysis of the behavior of individual scientists in an environment characterized by the availability of centralized project grant systems and decentralized institutional grant systems. We then examine the behavior of research administrators under the two research support systems. Finally, we attempt to draw some inferences from the behavior of research scientists and administrators under the two systems for research system efficiency. The analysis presented here provides a theoretical framework for the empirical evaluation of the gains and losses from the two systems of research management.

The Research Scientist

What objectives does the individual research scientist attempt to maximize? And how does the project (PR) and institutional (IR) research grant systems impinge on the behavior of the individual scientist?

The research scientist has been depicted as both hero (Stakman, Bradfield, Mangelsdorf) and villain (Berry). Our perspective is more modest. The typical research scientist is, as a result of inclination and conditioning, prepared to accept a rather high degree of deferred gratification within the professional reward system. In the immediate postdoctoral years, the scientist is usually willing to defer immediate financial reward for an appointment which assures continued professional development—preferably documented by the accumulation of evidence of research productivity in the form of published papers. If professional productivity is accompanied by reasonable advancement in rank and earnings, the initial research orientation is reinforced. If productivity lags or is not accompanied by advancement in salary or rank, there often is a shift in emphasis toward research that is valued by clienteles other than professional colleagues. This shift toward more applied research also may be associated with a transfer to another institution whose program is oriented more toward applied research. During this process the mid-career scientist may also develop certain entrepreneurial skills. These skills may run in the direction of capacity to generate research support from funding agencies and/or to mobilize the interest and the energies of colleagues to focus their efforts around problems of scientific or technical diversification which require a team effort. Development of entrepreneurial skills often comes at the expense of disciplinary capacity and direct involvement in research.

This description is, of course, highly simplified. And our ability to model is inadequate to deal with even this simplified view. However, we are able to identify several key elements of the individual scientist's objective function that appear directly relevant to the scientist's behavior under the institutional and project grant systems. (Since developing the model, our attention has been drawn to a similar model developed by Becker. His models are, however, designed to address different questions.)

The simplified behavior model that we have developed has the following characteristics:

(*a*) Each researcher maximizes some utility function by simultaneously allocating time between teaching, entrepreneurial activities such as seeking research support, actively working on research, and leisure. The use of leisure to represent nonwork related activities is a common methodological device.

(*b*) Research output is determined by the level of research support available to the researcher and the time spent actively working on research. The researcher faces diminishing returns both in the production of research funds and in the production of research.

(*c*) The transaction costs incurred by the individual researcher in obtaining project research support are greater than those incurred in obtaining institutional research support. However, the level of available IR support may be a binding constraint. That is, IR funds may be rationed and become unavailable before the researcher achieves the equilibrium allocation of time which maximizes utility.

(*d*) Income is a positive function of research output and some measure of teaching and/or extension (or public service) output depending on the way in which a particular scientist's appointment is defined.

Our goal is to determine the characteristics of the demand for research funds. Although several factors influence the individual scientist's demand for research funds, only the cost of obtaining grant and formula funds is considered. Factors held constant include the maximum amount of institutional funds available,

the preferences (utility function) of the researcher, the production function of research output, and the rewards from research output (the income production function). Varying the cost of obtaining research funds allows examination of the impact of alternative research management schemes. Only highlights of the model are presented but a detailed description and mathematical exposition is found in Bryant (available from the author upon request).

The results of the model depend critically on the hypothesis that the transactions cost of the PR system is significantly higher than those of the IR system. In other words the marginal productivity of time spent seeking institutional research funds is significantly higher than that seeking project research funds. Most university scientists can quote examples of the colleague who has spent much more time preparing grant requests for the support of summer research than was spent actually carrying out the grant-supported research. It also seems consistent with experience that the greater the degree of centralization of research management, the greater the costs of grant seeking and the costs of the review and allocation process.

The research scientist maximizes utility by allocating his time among active research, grantsmanship, and leisure (all other activities). Thus, the derivation of the demand for research funds (which reflects the allocation of time to grantsmanship) is similar to the derivation of the demand for a consumption good by the utility-maximizing consumer. However, research funds are an input in the production of research output. The derivation of the derived demand for research funds has certain similarities with the derivation of the derived demand for an input by a profit-maximizing firm.

Before deriving the implications of alternative research management programs, the implication of limited IR funds and different production functions for PR and IR funds are developed. The marginal product of time allocated to production of IR funds exceeds that of time allocated to production of PR funds. Logically, any time allocated to producing research funds will be allocated first to IR fund production. Time will be allocated to producing PR funds only upon exhausting available IR funds.

The assumption of greater cost to obtain PR funds coupled with the limitation on IR funds implies the marginal product of time allocated to production of research funds is a step function. The marginal product is illustrated in figure 1. The marginal product curve is derived simply by increasing the amount of time allocated to producing research funds. The conditions for utility maximization are not required to illustrate the characteristics of the marginal product curve.

Initially, any time allocated to producing research funds (T_k) will be used to produce IR funds (T_h). This maps the *ab* portion of the marginal product curve. At *b*, the amount of IR funds available (requiring a time allocation of T_h^{max}) is exhausted. Hence, additional allocations of time can produce only PR funds (T_g). But the marginal product of the first unit of time producing PR funds is less than the last unit producing IR funds. The differential costs result in the discontinuous portion of the curve, labeled *bc*. Allocation of time to producing research funds beyond T_h^{max} produces only PR funds mapping the *cd* portion of the marginal product curve.

To this point, the optimum allocation of time has not been considered. The desired statement of the demand for research funds reflects alternative research management schemes. The cost of obtaining research funds is varied by shifting the marginal product curve illustrated in figure 1. A reduction (increase) in the cost (marginal product) of obtaining research funds shifts the curve upward. To determine the characteristics of the demand for research funds, the marginal products of time producing formula and grant funds are exogenously and proportionately varied.

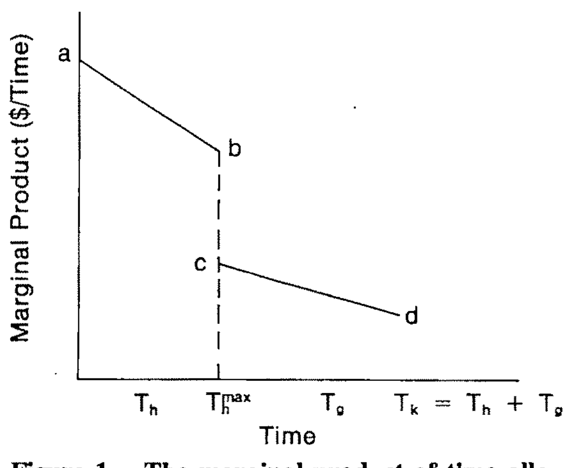

Figure 1. The marginal product of time allocated to obtaining research funds

In the analysis, increases in the marginal productivity of time allocated to producing research funds is synonymous with a reduction in the cost of obtaining research funds. Cost in this context may be thought of as the amount of time in other activities (and the associated income and utility) that must be foregone in order to obtain research funds. That cost reflects the research management system.

Initially, assume the cost (marginal product of time) of research funds is relatively high (low). At equilibrium, relatively little time is allocated to producing research funds (K). Hence, a relatively small amount of research funds will be demanded. Further decreases (increases) in the cost (marginal product) will increase the demand for IR funds until all available IR funds are exhausted (K_h^{max}). This maps the *ab* portion of the demand for research funds illustrated in figure 2.

Further decreases in the cost of research funds will not increase the quantity of research funds demanded. The optimum allocation of time to producing research funds occurs along the discontinuous part of the marginal productivity curve (*bc* in figure 1). Hence, the discontinuous characteristic of the marginal product curve maps the *bc* portion of the demand curve for research funds.

Still further decreases in the cost of research funds induce the allocation of time to producing PR funds (K_g). This maps the *cd* portion of the demand curve for research funds. The effective demand for research funds is *abcd* as illustrated in figure 2. The implications of the

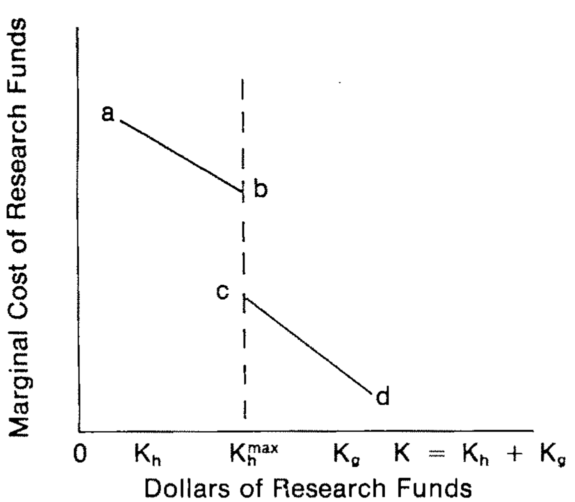

Figure 2. The individual's demand for research funds

step function characteristic of the demand for research funds are now developed.

First, at any institution there will be those scientists with so low a demand for research funds that they are not constrained by the limit on IR funds. These will be individuals who are very productive in nonresearch activities relative to research and those with high marginal products of labor in research relative to the marginal product of research funds. The former will specialize in teaching, extension, and administrative activities, while the latter will be the "pencil and paper" theorists. Both will operate within the *ab* portion of the demand for research funds and will not be affected by K_h^{max}. Of course, the more affluent the institution, the larger K_h^{max} likely will be for any individual. We would expect, therefore, interinstitutional differences in the proportion of faculty operating in the unconstrained *ab* portion of the curve. Depending on the allocating conventions of experiment stations, some fields may be allocated relatively more than others and so the scientists within these fields likewise will be less constrained.

Second, there likely will be a number of individuals at any institution who operate in the *bc* portion of the demand for research funds curve. Such individuals would demand more IR funds were such funds not rationed. But, they demand no competitive funds (K_g) because the marginal cost of K_g (the marginal value of the foregone leisure) is greater than the increment to income the added funds would bring. The number of such researchers who are thus "immobilized" depends, of course, on the length of the discontinuity, *bc*. It will be longer (and thence the frequency of immobilized researchers greater), (*a*) the greater the difference in the marginal costs of IR and PR funds, (*b*) the better substitutes research funds and researcher labor are in research, and (*c*) the better substitutes teaching, extension, administration, and research activities are in yielding income to the individual.

Third, within the range of the discontinuity, *bc*, while the demand for research funds is invariant, the amount of research done is not. Because he is barred from PR funds by their high marginal cost, the researcher may substitute his own labor for research funds and continue to increase research output, subject, of course, to greater diminishing returns than otherwise would exist. The labor intensity of the research, then, will increase as a result of

the limitation on IR funds and the high cost of competitive funds.[2] This labor intensity with respect to the primary researcher's labor also may involve changes in the research output mix: more theoretical work, more use of secondary data, smaller and fewer experiments, smaller and fewer instances of primary data generation as the research becomes more labor-intensive.

Fourth, another impact of the discontinuous demand for research funds is to increase the labor devoted by the scientist to other aspects of his (her) appointment: teaching, extension, administration. Consulting activities also can be expected to increase. Again, this bias toward nonresearch activities will occur to the extent that the individual has a positive demand for income (is not in the backward-bending part of his supply curve of labor), and the marginal wage rates for the nonresearch aspects of his (her) appointment are positive. Therefore, not only does the limit on IR funds and the high cost of competitive funds increase the labor intensity of the research enterprise of those caught in the discontinuity, it also has the effect of increasing the labor intensity of all other aspects of the individual's job.

Fifth, those not caught on the discontinuity and who have high enough demand for income (consumption) compete for PR funds and operate on the *cd* portion of the demand for research funds curve. The research outputs and incomes of such individuals are higher than those who operate on the *ab* and *bc* portions of the demand curve for the research funds. Because the marginal cost of PR funds is much higher than the cost of IR funds, the research funded with IR and PR funds will be more labor-intensive than the research of those operating on the unconstrained, *ab* portion of the curve. Whether the research done on the *cd* portion of the curve is more or less labor-intensive than those caught in the discontinuity depends on the difference in the marginal costs of PR and IR funds: the greater the difference, the more likely the research of those caught in the discontinuity will be more labor-intensive than those demanding PR funds. One way of looking at this is that as the difference between the costs of the two types of funds increases, more of the scientist's time must be devoted to grantsmanship and less to direct research activities if he (she) is to compete for PR funds.

Sixth, it is likely that a reduction in IR funds with the consequent increased stringency with which remaining IR funds would be rationed among researchers (a shift to the left of $K_h^{\max}$ in fig. 1) will increase the difference between the marginal costs of IR and PR funds. As IR funds are increasingly rationed, more individuals will be pushed from the *bc* to the *cd* portion of the demand for funds curve and will compete for PR funds. The increased number of competitors for PR funds will drive down the probability of acceptance of any given proposal and so raise the marginal cost of grantsmanship. A transfer of the reduced IR funds to PR purposes (as the USDA proposed in 1978) will increase either the number of PR projects funded or the level of funding per project and so increase the expected yield per proposal. The net effect of these two changes is unclear. If academics are as risk-averse as recent writings on the economics of academic tenure and retirement suggest, the decline in the probability may well be more important than the increase in PR funds. If so, the marginal cost of PR funds will rise. A possible result of transferring funds from IR to PR purposes, therefore, will be to increase the proportion of researchers immobilized in the *bc* portion of the curve.

Seventh, it is worth noting that given a distribution of grantsmanship skills among scientists, the greater the difference between the marginal costs of IR and PR funds, the greater the likelihood that specialization of function will arise among scientists. The more skilled as grantsmen will specialize in the activity doing little or no actual research.[3] And with the PR funds, they will hire scientists relatively more skilled in research to which they will allocate research funds.

The Research Administrator

An assessment of implications of a project research grant system relative to an institutional research grant system must consider the ef-

[2] In this instance and hereafter when labor intensity is discussed, it is researcher or project director labor that is being referred to. Within the limits of IR and PR funds, other labor (graduate students, postdoctoral fellows, research assistants, secretaries, and the like) may be employed to carry out particular facets of the research.

[3] There is some evidence to the effect that younger scientists are more active in journal publication than older scientists and that the marginal value of a journal article, in terms of income, declines with the scientist's age (Peterson 1973, p. 14).

fects of the two systems on the behavior of the individual scientist. In this section we suggest how the project and institutional research grant systems impinge on the behavior of the research administrators. We shall be particularly concerned with the impact on the behavior of the director of an agricultural experiment station, research center, or laboratory located within a university environment.

Our description of the objective function of the research administrator is largely intuitive. Kaldor (1971, 1978) repeatedly has pointed to the dearth of systematic knowledge about the decision-making processes used by research administrators. Most of the knowledge that we do have is based on casual observation and introspection. Nevertheless it does seem feasible to specify some of the elements that enter into the decisions of research administrators and scientists.

The typical research manager tends to have a view of the world which places a heavy weight on the value of new knowledge and new technology and places a low weight on both the direct and indirect costs of research and of technological change. The administrator visualizes an almost "endless frontier" waiting to be discovered, with limited financial, physical, and professional resources. The administrator's standing, both within his (her) own institution and among outside collegiate and clientele constituencies, is directly related to the ability to assemble or develop a research staff that is recognized for the quality of its work or its value to clientele constituencies. Within public sector institutions, where the salary structure is somewhat bureaucratically determined and has little flexibility at the top, prestige considerations carry greater weight. In the private sector, where the output of the research laboratory is evaluated more directly in terms of the enhancement of the firm's profits, productivity is given more weight.

The net effect of these considerations leads a research director to measure success in terms of the capacity to acquire additional resources and the ability to utilize these resources productively. The measurement of the quality or the value of research output at the individual scientist or research team level is highly subjective, and the management of research enterprises is highly collegial. These factors tend to lead to an emphasis on the quality of the major input, professional personnel, relative to the value of research output. Emphasis on more effective monitoring of research output is greatest in those cases where there is strong clientele pressure. Clientele pressure on research management is reasonably strong in state and federal agricultural research programs because of the close feedback loop between farmers, legislators, and research institutions (Hayami and Ruttan, Guttman).

The above description of the elements that enter into the objective function of the research administrator or manager is not inconsistent with the utility function of the bureau manager that has been suggested in the literature on bureaucratic behavior (Niskanen; Ruttan). In that literature it is assumed that the bureau manager's utility is a function of (*a*) the bureau's output, (*b*) the bureau's discretionary budget. In the case of the agricultural experiment station or the agricultural research institute, we can interpret bureau size in terms of research staff and the output of applied research that is valued by the research institution's clientele. Discretionary budget can be interpreted in terms of funds to support more fundamental (basic or supporting) research and for related professional activities (seminars, symposiums) that serve to enhance the capacity of the research staff or the prestige of the research unit. It represents funds that are not required to meet salaries and other overhead items. This description of the utility function of the research manager involves an even greater simplification of a complex reality than our description of the utility function of the individual research scientist. It does, however, appear to capture important elements of the research manager's motivation.

If incremental growth in research funding is primarily in the form of project rather than institutional research support, as suggested in the introductory section, one effect will be to reduce the discretionary resources available to state experiment station directors. A higher proportion of institutional support funds will have to be devoted to salary and overhead items. Capacity to mobilize resources for problems of significance at the state or regional level will be reduced.

We are now ready to combine our analysis of the effects of the institution research grant (IR) and the project research grant (PR) systems on the behavior of the individual scientist and research administrator, on the efficiency

or the productivity of the research system, and on the strategy alternatives available to research administrators.

Some Research Management and Policy Implications

The goal of a research management system is the production of the socially desired mix of research output at the minimum social cost. Our analysis suggests that the institutional research management system entails lower transactions costs than the project research management system. On the other hand, the project research management system enables the control of the mix of research output at a central (national) level. Advocating one system in preference to the second involves the trade-off between central control and system efficiency.

Research Efficiency

It would be surprising, however, if optimization of the objective functions of research scientists and administrators would lead under most circumstances to system efficiency. System efficiency is a function of the institutional environment, including the structure of incentives and constraints, in which scientists and administrators carry out their professional responsibilities. When we examine the implications for the behavior of scientists and research administrations under the IR and PR systems, some rather clear-cut empirical generalizations concerning system efficiency emerge.

First, the external PR grant system diverts efforts by individual scientists from research to grant seeking and related entrepreneurial activities (Foster 1979a, b). This is why the PR portion (section *cd*) of the individual researcher's demand for funds lies below the IR portion (section *ab*). More directly to the point, in 1978 the U.S. Department of Agriculture (USDA), which administered a competitive grant program of $15 million, received more than 1,100 research proposals involving funding requests for over $200 million (USDA 1978b). Similar ratios have been noted for other grant programs (Leopold). In addition to the time devoted to the preparation of unfunded grant proposals, substantial time also is devoted to peer review and administration.

A major structural feature of the competitive grant system clearly induces excessive allocation of scientific effort to grant-seeking activity. To the individual researcher, the supply of PR funds appears relatively elastic (with respect to effort devoted to grant seeking). Each individual project is small relative to the resources available to the granting agency. In the aggregate, however, the supply of research funds is relatively inelastic in the short run. An increase in the number of projects submissions results in an increase in the share of research resources devoted to grant seeking relative to research and an increase in the bureaucratic resources devoted to grant management. It also may result in smaller average size of individual grants and fragmentation of research effort.

Second, in a system which limits institutional support primarily to personnel support for core scientific staff (such as tenured professors) and capital equipment (such as laboratory space and computing equipment), incremental research costs must be covered by project grants. Over time, a research institute committed to solving a particular scientific and technological problem, adapting soybeans to shorter growing season environments for example, may find its staff responding more to priorities of external funding institutions rather than concentrating its effort on the crop improvement mission. It is not difficult to imagine a situation where a university administration begins to value its agricultural (or space science) research capacity less for the significance of the scientific and technological knowledge it produces than for the overhead generated by research grants or contracts.

This problem appears to be most acute in situations in which institutional research support has been closely linked to, or hidden by, reduced teaching loads. In the 1950s and 1960s many universities used expansion of undergraduate education to support the expansion, almost surreptitiously, of their institutional research support (Keyfitz). This has created two important problems in a period of declining or shifting undergraduate enrollment. Institutional research support by discipline or problem area expanded in response to differential rates of growth in undergraduate enrollment. Likewise during a period of declining or shifting enrollment, institutional support is eroded

for considerations unrelated to scientific opportunity or technological priority. As noted earlier, institutional support for agricultural research has not been as closely coupled to undergraduate enrollment as in many other areas. There are, however, substantial pressures in some states from university administrators and state legislative committees to conform to university-wide standards with respect to student-teacher ratios. In the future, effective allocation of institutional research resources will require the development of budgeting mechanisms that more effectively uncouple the institutional support for teaching and research activities.

Research Mix

One major advantage that is sometimes claimed for a project grant system is its flexibility in redirecting research effort into areas of new scientific interest or technical concern. Research systems that rely primarily on institutional support have been characterized as limited in their capacity to reallocate scientific and financial resources from traditional areas of concern or staff capacity to new areas. The state agricultural experiment stations in the United States have been criticized for devoting excessive attention to problems of increasing food and fiber production and as unresponsive to environmental and human concerns in a period of changing social values (Paarlberg). In the United Kingdom, the national agricultural research institutes were criticized in the Rothschild report for devoting too much attention to basic research and being unresponsive to the needs of the farmer and the food industry (Ulbricht).

A second argument that is sometimes made for a competitive project grant system is that it creates a marketlike environment for both talent and ideas. This argument frequently is coupled with arguments in favor of a peer review system to assure competent scientific judgment and effective quality control in the allocation of research resources (Cole, Rubin, Cole; Bowers; Gustafson).

Both arguments have a great deal of intuitive appeal when used to support the proposition that a centralized project research grant is itself a powerful force for conformity. We have great difficulty, for example, visualizing how a peer panel might have reacted in 1900 to a proposal from a young physicist named Einstein, who had just published his first professional paper, for support of a project which had as an objective the development of a unified theory embracing mechanics, optics, and electrodynamics—and without resort to conventional laboratory technique.

The Management of Research at SAES

The sources of funds available to U.S. state agricultural experiment stations have consisted primarily of federal funds appropriated to the states on a formula basis and of funds appropriated for agricultural research by state legislative bodies (table 1). Although federal "formula" funds are granted to the state on a matching basis, in recent years most states have supported agricultural research at a level that substantially exceeds the federal matching requirements. In addition to federal and state funds, many state agricultural experiment stations also obtain substantial contract and grant support from private industry, private foundations, the U.S. Department of Agriculture, and from other federal and state sources. The contract and grant support from other federal agencies and other sources has tended to increase slightly more rapidly than the traditional sources of funds.

The last decade has been characterized by a growing lack of confidence in research decision-making processes (Berry; Bonnen; Hadwiger; Mayer and Mayer; Meier; Paarlberg). In the United States the agricultural research establishment has been viewed as unresponsive to environmental, distributional, and humanitarian concerns. New clientele groups have attempted to move concerns such as nutrition, rural development, environmental impact, soil conservation, and the problems of hired workers higher on the research agenda.

Partially in response to this criticism, Congress established a federally funded, competitive, research grant program open to all scientists and administered by the Competitive Research Grants Office of the USDA Science and Education Administration.[4] The FY 1978 appropriation act made a total of $15 million available for competitive research grants. The executive budget for FY 1979 proposed that the competitive grants program be increased by an additional $15 million (table 2). This was

[4] A program of special grants that were competitive among state agricultural experiment stations was initiated in 1970. These funds rose from $2.8 million in 1970 to $16.2 million in 1979 (table 1).

Table 1. Amount and Relative Importance of Federal, State, and Other Funding Sources for State Agricultural Experiment Stations, 1967 and 1977

	1967		1977	
	Amount[a]	Percent	Amount	Percent
Federal sources				
Science and Education Administration (USDA)[b]	53.8	23.1	118.8	19.1
Cooperative Grants and Agreements (USDA)	10.3	4.4	12.6	2.0
Other federal agencies	24.1	10.3	55.6	8.9
	88.2	37.8	187.0	30.0
State sources				
Appropriations	118.6	50.8	341.2	54.9
Sales	13.5	5.8	39.1	6.3
	132.1	56.6	380.3	61.2
Other sources	13.1	5.6	54.6	8.8
Total	233.4	100.0	621.9	100.0

Source: USDA CRIS printout. (FY 1977 data are preliminary. FY 1978 and FY 1979 are not yet available.) The authors are indebted to Roland Robinson of the USDA Science and Education Administration for assistance in obtaining the CRIS data.
[a] Amounts are in hundred thousands of dollars.
[b] Funds received by states differ from funds appropriated by the amount of direct and indirect federal administrative charges.

offset by a reduction of approximately $11 million in Hatch Act formula funding plus reductions of approximately $1.0 million in McIntire-Stennis Cooperative Forestry Research, $2.0 million in special research grants, and $1.5 million in rural development research (USDA 1978a, c; Strobel). The 1979 appropriations act finally passed by Congress restored the cuts in Hatch Act funds that had been recommended by the administration and continued the competitive research grant program at the $15.0 million level. The executive budget for FY 1980 proposed a continuation of Hatch funding at the FY 1979 level and an increase in the competitive grants program from $15.0 to $30.0 million. The FY 1980 appropriations, however, increased Hatch funding by $9.5 million and the competitive grant program by only $1 million.

Strong support for a program of competitive

Table 2. Funds Appropriated for Agricultural Research under Cooperative Research Programs of the USDA Science and Education Administration

	1977		1978		1979		1980 Budget	
	Amount[a]	Percent	Amount	Percent	Amount	Percent	Amount	Percent
Cooperative research								
Hatch Act[b]	98.0	76.0	109.1	69.0	109.1	62.6	118.6	62.8
— Regular	73.1	56.7	81.1	51.3	81.1	46.5	87.9	46.5
— Regional	21.7	16.8	24.5	15.5	24.5	14.0	26.9	14.2
McIntire-Stennis[c]	8.2	6.4	9.5	6.0	9.5	5.4	10.0	5.3
1890 Colleges and Tuskegee Institute	13.4	10.4	14.2	9.0	16.4	9.4	17.8	9.4
Special research grants	6.3	4.9	7.2	4.6	16.2	9.3	17.7	9.4
Competitive research grants	—	—	15.0	9.5	15.0	8.6	16.0	8.4
Animal health and disease	—	—	—	—	5.0	2.9	6.0	3.2
Rural development	1.5	1.2	1.5	0.9	1.5	0.9	1.5	0.8
Federal administration	1.7	1.3	1.7	1.1	1.7	9.7	1.5	0.8
Total	129.0	100.0	158.2	100.0	174.4	100.0	189.0	100.0

Source: USDA, SEA, and CSRS memoranda to state agricultural experiment station directors.
Note: Prior to 1978 the Cooperative State Research Service (CSRS).
[a] Amounts are in hundred thousands of dollars.
[b] Total includes regular and regional funds distributed to states plus federal administration and penalty mail.
[c] Cooperative forestry research.

project research grants to be administered by the USDA had been made in two reports sponsored by the National Research Council (1973, 1977). The National Research Council recommendations reflected, in part, a judgment that the productivity of agriculture and agriculturally related research could be enhanced by making USDA research support available to scientists in departments and institutions that had not been eligible for support under the formula-funding arrangements.

Administrative officers and scientists at the state agricultural experiment stations also had been generally supportive of the move to expand funds for competitive grants (Babb). Both the National Research Council and the leadership of the state experiment stations, however, had expected that an expansion of funds for competitive research grants would take place in an environment of expanded support for agricultural research. Apparently they did not anticipate the trade-off between the competitive grant and formula funding that emerged in the FY 1978 executive budget proposal.[5]

The argument for expanding support for agricultural research typically has drawn on two sources of support. Agricultural scientists and science administrators have pointed to the technical constraints that must be overcome to meet future food and fiber requirements. They also have argued that technical change leading to lower production costs represents one way of balancing the conflicting claims of farmers for higher incomes and of consumers for restraint in food price increases. Economists have buttressed these arguments with an expanding body of empirical research which has documented the high rates of return to past agricultural research (Boyce and Evenson; Bredahl and Peterson; Arndt and Ruttan). In recent years, they also have worked closely with research administrators to provide *ex ante* rate of return projections.[6] Both the constraint and the rate-of-return approaches suggest substantial underinvestment in agricultural research both in the United States and in most other countries where such studies have been conducted.

Evaluation of Current Research Policy

We have noted that the effect of a system which appears optimal to the individual scientist or to the individual research manager in a world characterized by limited institutional support and substantial project research support alternatives is to (*a*) induce both excessive allocation of professional resources to grant seeking and (*b*) contribute to the disintegration of the capacity to undertake major mission-oriented applied research programs. These two sources of inefficiency can be reduced by utilizing an institutional research strategy as the primary device for the support of mission-oriented applied research and for basic research which directly relates to the needs of an applied research program.

There is substantial evidence to support the claim of efficiency for the institutional support system. High rates of return have been attributed to the state and federal agricultural research systems in the United States, to a number of older research institutions in former colonial countries (such as the Rubber Research Institute of Malaysia), and to the older units of the CGIAR-sponsored international agricultural research system (Evenson; Evenson, Waggoner, Ruttan). It would be extremely difficult to imagine that the long-term research effort required to develop the high-yielding clones which have revolutionized productivity in the Malaysian rubber industry could have been accomplished on the basis of a series of project grants from a colonial research secretariat in London.

The inferences drawn from agricultural research are consistent with the experience of a number of highly productive industrial research programs. Mansfield et al. (p. 157) have documented rates of return to industrial research in the same range as the rates of return to public sector agricultural research. The more productive private research programs typically have been those which have combined long-term sustained support by a firm with a sufficiently broad product line to be

[5] Dr. M. Rupert Cutler, Assistant Secretary for Conservation, Research, and Education, USDA, appeared to be surprised by the results of his own budgeting efforts. In response to committee questioning on this point he responded (p. 91, 92), "That apparent relationship was unintended. By that I mean the relationship between beginning a competitive grant research program open to all agricultural scientists and the level of the Hatch Act budget request." Cutler went on to explain that many of the programs of the USDA (entitlement and regulatory programs) are legislatively determined. Given a budget ceiling, the remaining funds available for agricultural research programs are fixed. Thus the only available method to initiate the competitive grants system was the reduction of other research areas.

[6] For a review of the methodologies for estimating *ex ante* values of return see Fishel, Puterbaugh, and Shumway. For an attempt to develop *ex ante* rate-of-return estimates see Araji, Sim, and Gardner.

able to utilize a substantial share of the product of a major "in-house" research program (Mueller).

Finally, one can point to the productivity of a number of long-term institutional research support activities by the private foundations. The support by the Carnegie Institution for the fundamental studies on inheritance in maize by George H. Schull is a classic example (Sprague). The Rockefeller Foundation support for the research program of the Office of Special Studies in the Mexican Ministry of Agriculture over several decades (from the mid-1940s to the early 1960s) established the basis for the research program of international research centers which are part of the Consultative Group on International Agricultural Research (CGIAR) system. The Ford Foundation institutional support for the research program of Resources for the Future has been a major factor in establishing resource economics as a major field of economic research in the United States.

Qualifications and Conclusions

Long-term institutional research support also can become a source of inefficiency. Institutional research programs are subject to the danger of becoming too conventional or of losing a sense of urgency with respect to their mission. We noted earlier that project grant support has been defended on the basis that it forces a research system to become more responsive. We find no fault with this argument as long as project research support remains relatively small—as long as its impact is to encourage the exploration of new opportunities within the broad research mission of an institution.

There are also other devices for offsetting geriatric tendencies in a mature research institute. The development of cost-sharing arrangements between public research institutes and clientele groups, or user representation on boards of directors or advisory committees, and use of periodic peer review panels are among the possibilities. An important factor in the case of the state agricultural experiment stations has been their location within a university environment. The interaction between graduate training and research and the opportunities to draw on professional capacity in related fields have contributed to research productivity.

Another argument which must be dealt with is whether a competitive PR support system is an effective way of taking advantage of the research capacities that exist outside of institutionally funded research programs. A major argument in favor of the new USDA project grant program is that it would be able to draw on professional resources in departments that do not receive experiment station funding and in institutions that were not part of the land grant system. An analogy often is made with the project grant programs of the National Science Foundation, which frequently supports the research of individual scientists in institutions which have very little institutional research capacity.

This argument is only partially compelling. The United States has been reasonably successful in evolving a dual system of colleges and universities in which those institutions that are capable of organizing effective graduate training and research activities are sharply differentiated from those that do not possess such capacity. The major research universities probably have greater capacity to manage efficiently a program of research grants based primarily on the quality of individual projects than a central granting agency such as the USDA or the National Science Foundation.

For the colleges and universities which do not have substantial graduate programs, faculty research must be justified primarily on the basis of contribution to the viability of the teaching programs. A limited commitment of faculty effort to scholarship and research contributes to the vitality of undergraduate teaching programs. Even in institutions that are primarily committed to an undergraduate education mission, our experience on university and agency research review panels leads us to believe that institutional support for a program of small grants would be more efficient than a grant program that is centralized in a Washington agency.

In our view, the current argument about the merits of institutional (IR) and project (PR) research support more appropriately is cast in terms of the relative mix of the two systems of support than in the absolute merits of either system. We do, however, insist that the issue of efficiency in the allocation and use of research resources is important. The productivity of agricultural research judging from historical rates of return has been high. This places a heavy burden on those who would argue for

the shift of resources from institutional to project support to demonstrate that such a shift would either enhance the productivity of the existing level of research support or draw substantial new resources into the agricultural research system.

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References

Araji, A. A., R. V. Sim, and Richard Gardner. *Returns to Public Investment in Agricultural Research and Extension in the Western Region.* Dep. Econ., University of Idaho, Jan. 1978.

Arndt, Thomas M., and Vernon W. Ruttan. "Valuing the Productivity of Agricultural Research." *Resource Allocation and Productivity in National and International Agricultural Research,* ed. Thomas M. Arndt, Dana G. Dalrymple, and Vernon W. Ruttan, pp. 3–25. Minneapolis: University of Minnesota Press, 1977.

Babb, Emerson M. *Marketing Research at State Agricultural Experiment Stations: Problems and Possible Solutions,* pp. 12–25. Purdue University Agr. Exp. Sta. Bull. 150, Jan. 1977.

Becker, William E., Jr. "Professional Behavior Given a Stochastic Reward Structure." *Amer. Econ. Rev.* 69 (1979):1010–17.

Berry, Wendell. *Culture and Agriculture: The Unsettling of America.* New York: Avon, 1978.

Bonnen, James T. "The Crisis in the Traditional Roles of Agricultural Institutions." *Agricultural Policy in an Affluent Society,* ed. Vernon W. Ruttan, Arley D. Waldo, and James P. Houck, pp. 48–62. New York: W.W. Norton & Co., 1967.

Bowers, R. "The Peer Review System on Trial." *Amer. Scientist* 6(1975):624–26.

Boyce, James K., and Robert E. Evenson. *National and International Agricultural Research and Extension Programs.* New York: Agricultural Development Council, 1975.

Bredahl, Maury E., and Willis L. Peterson. "The Productivity and Allocation of Research: U.S. Agricultural Experiment Stations." *Amer. J. Agr. Econ.* 58(1976):684–92.

Bryant, W. Keith. "The Faculty Member as a Teacher and a Researcher: A Mathematical Model with Implications of Grant Versus Institutional Research Support." RP80-1, Dep. Consumer Econ. and Housing, Cornell University, Jan. 1980.

Cole, Stephen, Leonard C. Rubin, and Jonathon R. Cole. "Peer Review and the Support of Science." *Scientific Amer.* 237(1977):34–41.

Cutler, M. Rupert. "Statement." *Appraisal of Title 14 (Research), Agricultural Act of 1977,* pp. 91, 92. Hearings before the Subcommittee on Department Investigations, Oversight and Research, of the House Committee on Agriculture, 23 Feb. 1978.

Dalrymple, Dana. "Comment on 'Public Purpose in Agricultural Research and Education'." *J. Farm Econ.* 44(1962):444–53.

Dupree, A. Hunter. *Science in the Federal Government: A History of Policies and Activities to 1940.* Cambridge, Mass.: Harvard University Press, 1957.

Evenson, Robert E. "Comparative Evidence on Returns to Investment in National and International Research Institutions." *Resource Allocation and Productivity in National and International Agricultural Research,* ed. Thomas M. Arndt, Dana G. Dalrymple, and Vernon W. Ruttan, pp. 237–64. Minneapolis: University of Minnesota Press, 1977.

Fishel, Walter L., ed. *Resource Allocation in Agricultural Research.* Minneapolis: University of Minnesota Press, 1971.

Foster, Edward. "The Treatment of Rents in Cost-Benefit Analysis." Center for Economic Research, Dep. Econ. Disc. Pap. No. 79-106, Jan. 1979a. University of Minnesota.

———. "Competitively Awarded Federal Grants." Mimeographed. Dep. Econ., University of Minnesota, Jan. 1979b.

Gustafson, T. "The Controversy over Peer Review." *Science* 190(1975):1060–66.

Guttman, Joel M. "Interest Groups and the Demand for Agricultural Research." *J. Polit. Econ.* 86(1978): 476–84.

Hadwiger, Don. "Changes in Political Support for Agriculture." *Food and Agriculture Policy Issues,* ed. Luther Pickrel, pp. 43–49. University of Minnesota Agr. Extens. Serv. Spec. Rep. 71, 1978.

Hayami, Yujiro, and Vernon W. Ruttan. *Agricultural Development: An International Perspective.* Baltimore, Md.: Johns Hopkins University Press, 1971.

Heady, Earl O. "Public Purpose in Agricultural Research and Education." *J. Farm Econ.* 43(1961):566–81.

———. "An Alternative View of State Expenditures." *J. Farm Econ.* 44(1962):454–61.

Huffman, Wallace E., and John A. Miranowski. "An Analysis of State Expenditures on Experiment Station Research." Mimeographed. Dep. Econ., Iowa State University, Mar. 1978.

Kaldor, Donald R. "Social Returns to Research and the Objectives of Public Research." *Resource Allocation in Agricultural Research,* ed. Walter L. Fishel, pp. 62–79. Minneapolis: University of Minnesota Press, 1971.

———. "Some Issues in Specifying an Objective Function for Evaluating Public Agricultural Research." Mimeographed. Dep. Econ., Iowa State University, 1978.

Keyfitz, Nathan. "The Impending Crisis in American Graduate Schools." *The Public Interest* 52(Summer 1978):85–97.

Leopold, A. Carl. "The Burden of Competitive Grants." *Science,* no. 203 (1979), p. 607.

Mansfield, Edwin et al. *The Production and Application of New Industrial Technology.* New York: W.W. Norton & Co., 1977.

Mayer, Andre, and Joan Mayer. "Agriculture, the Island Empire." *Daedalus,* no. 103 (Winter 1974), pp. 83–96.

Meier, Kenneth J. "The Agricultural Research Service and Its Clientele: The Politics of Food Research." Paper presented at the 1977 annual meeting of the Southwestern Political Science Association, Dallas, 1977.

Mueller, Willard F. "The Origins of Basic Inventions Underlying duPont's Major Product and Process Innovations, 1920–1950." *The Rate and Direction of Inventive Activity,* ed. Richard R. Nelson, pp. 323–53. Princeton, N.J.: Princeton University Press, 1962.

National Research Council. *Report of the Committee on Research Advisory to the USDA.* Springfield, Va.: National Tech. Infor. Serv., 1973.

———. *World Food and Nutrition Study: The Potential Contributions of Research.* Washington, D.C.: National Academy of Sciences, 1977.

Niskanen, William A. "Bureaucrats and Politicians." *J. Law and Econ.* 18(1975):617–44.

Paarlberg, Don. "A New Agenda for Agriculture." *Policy Stud. J.* 6(1978):504–06.

Peterson, Willis L. "The Allocation of Research, Teaching, and Extension Personnel in U.S. Colleges of Agriculture." *Amer. J. Agr. Econ.* 51(1969):41–55.

———. "Publication Productivities of U.S. Economics Department Graduates." Staff Paper P73-27, Dep. Agr. and Applied Econ., University of Minnesota, Oct. 1973.

Puterbaugh, Horace L. "An Application of PPB in the Agricultural Research Service." *Resource Allocation in Agricultural Research,* ed. Walter Fishel, pp. 316–25. Minneapolis: University of Minnesota Press, 1971.

Ruttan, Vernon W. *Bureaucratic Productivity: The Case of Agricultural Research.* Dep. Agr. and Applied Econ. Staff Pap. P78-16, University of Minnesota, Nov. 1978.

Shumway, C. Richard. "Models and Methods Used to Allocate Resources in Agricultural Research: A Critical Review." *Resource Allocation and Productivity in National and International Agricultural Research,* ed. Thomas M. Arndt, Dana G. Dalrymple, and Vernon W. Ruttan, pp. 436–57. Minneapolis: University of Minnesota Press, 1977.

Sprague, George F., ed. *Corn and Corn Improvement.* New York: Academic Press, 1955.

Stakman, E. C., Richard Bradfield, and Paul C. Mangelsdorf. *Campaigns Against Hunger.* Cambridge, Mass.: Harvard University Press, 1967.

Stein, Bernard R. "Public Accountability and the Project Grant Mechanism." *Res. Pol.* 2(1973):2–16.

Strobel, Gary A. "A New Grants Program in Agriculture." *Science,* no. 199 (1978), p. 935.

Ulbricht, Tilo L. V. "Contract Agricultural Research and Its Effect on Management." *Resource Allocation and Productivity in National and International Agricultural Research,* ed. Thomas M. Arndt, Dana G. Dalrymple, and Vernon W. Ruttan, pp. 381–93. Minneapolis: University of Minnesota Press, 1977.

U.S. Department of Agriculture, Cooperative State Research Service. *Funds for Research at State Agricultural Experiment Stations and Other Cooperating Institutions.* Washington, D.C.: CSAS 15-11, Jan. 1976.

U.S. Department of Agriculture, Science and Education Administration. "Competitive Grants for Basic Research: Plant Biology and Human Nutrition." *Federal Register,* vol. no. 43, 7 March 1978a, pp. 9432–40.

———. *To Administrators of Cooperating State Research Units.* Washington, D.C.: Exp. Sta. Letter 1455, 26 May 1978b.

———. To *Directors of State Research in Agriculture and Forestry.* Exp. Sta. Letter 1438, 27 Jan. 1978c.

The Role of the Marital Deduction in Planning Intergenerational Transfers

David Reinders, Michael Boehlje, and Neil E. Harl

The marital deduction is an important and commonly used estate-planning tool. The optimal marital deduction should be chosen to minimize the present value of the tax outlays at the deaths of both the husband and wife given the expected growth rate, the appropriate discount rate, the expected time of death of the surviving spouse, the distribution of wealth between the spouses, and the total wealth of both spouses. The typical practice of claiming the maximum marital deduction allowed by law or the amount that just reduces the tax liability of the decedent to zero does not necessarily produce an optimal result.

Key words: estate planning, estate taxation, linear programming, optimal marital deduction.

For individuals and couples owning sufficient property for their estates to incur estate taxation, planning for the disposition of their property during life and after death may include attempts to minimize federal unified gift and estate (and state death tax) liabilities. For those unmarried at the time of death, important strategies for reducing the federal estate tax liability include claiming the allowable deductions and credits, using special provisions such as use valuation of real property and alternate date of valuation to determine the value at which property is included in the gross estate, and making gifts during life.[1] (See also Case, Barnett, for other post-mortem estate-planning techniques.) The allowable deductions at death include funeral costs, medical expenses, costs of administering the estate, outstanding debts and obligations of the decedent, an orphan's deduction, and a charitable deduction. Credits available at death include the unified credit, credit for state death taxes paid, credit for gift taxes paid, and a credit on prior transfers.

Planning involving married couples may include an additional factor, the marital deduction. The marital deduction is available only for property passing to a surviving husband or wife; it is not available in the estate of a widow, widower, or unmarried person. For deaths after 1976, the maximum marital deduction can be the greater of $250,000, or 50% of the adjusted gross estate, but under no circumstances can it exceed the amount of property passing to the surviving spouse.[2] Furthermore, for property to qualify for the marital deduction, the surviving spouse must have sufficient control over the assets received so that the marital deduction property (if retained) will be included in his (her) estate at the subsequent death. Two common examples of property interests that would qualify for the marital deduction are fee simple and a life estate plus a general power of appointment (IRC § 2056[b][5]).

Thus, the marital deduction becomes a key decision variable in estate planning for married couples. This article provides a mathematical and computational base for determining the optimal-size marital deduction.

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[1] Every donor is entitled to an annual exclusion of up to $3,000 per beneficiary per year without paying federal gift tax. For gifts made by a husband and wife, the exclusion becomes $6,000 per beneficiary per year. Making gifts to noncharitable beneficiaries larger than the annual exclusion results in use of the unified credit which could have been used at death.

[2] The maximum available federal estate tax marital deduction may be less than the greater of $250,000, or 50% of the decedent's adjusted gross estate if gifts are given to a spouse. If the federal gift tax marital deduction claimed exceeds what the gift tax marital deduction would have been, had it been set at 50% of the amount reported as a gift to the spouse, the excess is subtracted from the allowable estate tax marital deduction I.R.C. § 2056.

Conceptual Model

The marital deduction has received considerable attention in the literature. Many analysts have identified the marital deduction as one of a number of estate-planning tools available (Boehlje and Eisgruber; Levi and Allwood; Harl 1977; Harl and Boehlje) and the dimensions to be considered in choosing the optimal marital deduction have been described (Harl; Harl and Boehlje; and Harl 1979a,b). Some researchers have addressed the question of the correct legal terminology to use in structuring the marital deduction as part of the process of drafting the will (Barnes; Thomas, Esperti, Katz); others have investigated how the marital deduction share should be funded (Brode; Harl 1979a,b,c, 1977). While some analysts have recognized that it is not always advantageous to utilize the maximum marital deduction allowable (Allington; Thomas, Esperti, Katz), these studies have not considered explicitly such economic concepts as economic optimization and the time value of money.

Analytical Framework

The purpose of this article is to provide an analytical and empirical framework to determine the optimal marital deduction; a framework that explicitly considers in a present value context the appreciation in value of assets over time, the age and health of the survivor, the distribution of wealth between the spouses, and the combined estate size of both spouses.[3]

The role of the marital deduction is illustrated in figure 1. Assume a husband and wife have estates defined as A_1 and A_2 and that the spouse owning estate A_1 dies first at time t. The marital deduction property (MD) passes to the surviving spouse in fee simple or at least in trust or a life estate plus a general power of appointment. The nonmarital deduction property typically passes to the survivor for life in trust or in a legal life estate.[4] At the first death,

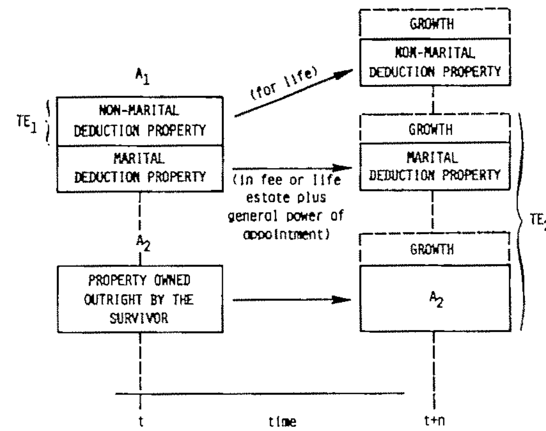


Figure 1. The marital deduction

only the nonmarital deduction property is taxed (TE_1). At the death of the survivor—time $t + n$—all property owned outright by the survivor (A_2) plus the earnings and growth in value on that property and the marital deduction property plus the earnings and growth in value on it (TE_2) are taxed. The nonmarital deduction property plus the earnings and growth in its value passes to the remaindermen.

Harl (1979a,b) has identified two basic estate-planning models. In Harl's Model I, property ownership is concentrated, usually in the husband's name, with the husband's will leaving a portion of his property (usually the maximum allowable marital deduction) to his wife in fee simple or in a life estate with a general power of appointment. The remaining property is left to the wife for life (in trust or legal life estate). For this model to minimize the estate tax liability, the husband must cooperate and die first.

In Harl's Model II, property ownership is divided equally between the spouses, with each spouse leaving his or her property to the other for life. This plan deliberately avoids qualifying property for the marital deduction and does not depend upon a particular order of death for its successful operation.

In addition, Harl has outlined (in his Modified Model II plan) the conceptual basis to accomplish the objective of minimizing the present value of the taxes and estate settlement costs (or maximizing wealth) after the deaths of both spouses.[5] In this plan property

[3] Funding of the marital deduction is important when the assets have different growth rates. But before this issue of optimal funding can be answered, the optimal size must be determined. Therefore, we assume all assets have the same growth rate and leave the questions of optimal funding for later research. Other related areas of investigation beyond the scope of this article include the interactions between the marital deduction and *inter-vivos* gifting, ten- and fifteen-year installment payment deferrals, and special use valuation.

[4] Alternatively the nonmarital share may pass directly to the children. The important point is that the nonmarital share must not be left with such ownership rights as would make it includable in the gross estate of the surviving spouse.

[5] Provided that the rates of growth on the property in the marital deduction share, the nonmarital deduction share and the property

ownership is divided equally between the spouses during life. At the first death, the marital deduction (not necessarily at its maximum) is used to decrease the taxable estate of the first to die and increase the taxable estate of the survivor. The size of the marital deduction becomes the key variable in implementing a Modified Model II plan, given the amount of property and ownership distribution between the spouses.

Developing balanced estates produces a property ownership pattern most likely to be compatible with tax minimization or wealth maximization. However, there are a number of reasons why balancing estate sizes during life may not be desirable or possible for the married couple. The spouse owning the majority of the property may not be willing to relinquish control, or the spouse with the smaller amount may not be willing to assume control. Also, gift tax consequences of transferring property during life may be prohibitive. And even if a well-designed gifting plan is initiated which would balance the estates at its completion, the fruits of the plan may never be realized because there is not sufficient time before the first death. In these cases, utilization of an optimal marital deduction is equally as important as in the Modified Model II plan, because the size of the marital deduction significantly influences tax liabilities at both the first and second death.

The Optimization Model

The optimal size of the marital deduction—whether that be none, the maximum allowed by law, or some value in between—depends upon the tax treatment of the property at both deaths and the desire to minimize these tax liabilities (maximize wealth transferred) as well as accomplishing other estate-planning goals. For purposes of our analysis, we will assume that minimizing the present value of the total tax outlays at both deaths is consistent with other family goals.[6] Thus, the optimal marital deduction should be chosen to minimize the present value of tax outlays given (*a*) the expected growth of assets between deaths, (*b*) the expected discount rate appropriate to the estate of the first to die for the period between deaths, (*c*) the expected time of death of the surviving spouse, (*d*) the distribution of wealth between the spouses at the time of the first death, and (*e*) the combined estate sizes of the spouses. This is a slight restatement of the five variables identified by Harl (1979a,b).

Specifically, the optimal marital deduction can be determined as that deduction (MD) which

$$(1)\quad \text{Minimizes } K = TAX_1 + \frac{TAX_2}{(1 + R)^N},$$

subject to: $TAX_1 \geq 0$, $TAX_2 \geq 0$, $0 \leq MD \leq$ maximum allowed by law, and R, G, ≥ 0, where

$$(2)\quad TAX_1 = t_1(A_1 - MD) - UC_1 - SDC_1,$$

$$(3)\quad TAX_2 = t_1[(A_2 + MD)(1 + G)^N] - UC_2 - SDC_2 - PTC,$$

$$(4)\quad SDC_1 = t_2(A_1 - MD),$$

$$(5)\quad SDC_2 = t_2[(A_2 + MD)(1 + G)^N], \text{ and}$$

$$(6)\quad PTC = (LE_c)(\%N)(TAX_1),$$

where

TAX_1 is the tax due at the death of the first spouse;

TAX_2, tax due at the death of the second spouse;

R, appropriate expected discount rate;

N, expected number of years between deaths based on actuarial data;

MD, marital deduction taken;

G, weighted average expected growth rate;

A_1, adjusted gross estate of the first spouse to die;

A_2, adjusted gross estate of the second spouse to die;

t_1, federal unified estate and gift tax rate schedule;

UC_1, unified credit available at the first death;

SDC_1, state death tax credit at death one;

UC_2, unified credit available at death two;

SDC_2, state death tax credit at death two;

t_2, federal credit for state death taxes paid rate schedule;

PTC, prior transfer credit;

LE_c, present interest of the surviving spouse in the property of the nonmarital deduction trust (This coefficient is given by law based upon the age of the surviving spouse at the time of the first death.);

owned outright by the surviving spouse are equal, the maximization of wealth passing to the heirs after both deaths is equivalent to the minimization of the present value of the tax outlays over both deaths.

[6] Goals and objectives of the family which are in conflict with the optimal marital deduction can be incorporated into the analysis by imposing additional constraints. For simplicity, we will only address unconstrained optimization in this analysis.

$\%N$ is the percentage of the prior transfer credit available as a result of the time which has passed between deaths. The percentage schedule is:

Time (years) between Deaths	$\%N$
0–2	100
2–4	80
4–6	60
6–8	40
8–10	20
over 10	0

The objective is to minimize the present value of the taxes paid at both deaths, subject to the constraints that the taxes paid at each death must be positive or zero and that the marital deduction must be between zero and that allowed by law. The tax due at the first death is defined [eq. (2)] as the adjusted gross estate of the first spouse to die minus the marital deduction times the appropriate tax rate minus the unified and state death tax credits.[7] The tax due at the second death [eq. (3)] is calculated as the adjusted gross estate of the surviving spouse plus the marital deduction compounded at the expected growth rate times the appropriate tax rate minus the unified, state death tax, and prior transfer credits. The state death tax credits are a function of the estate size [eq. (4) and (5)], and the prior transfer credit is a function of the surviving spouse's present interest in the nonmarital deduction property, the elapsed time between deaths, and the tax due at the death of the first spouse to die [eq. (6)].

The size of the marital deduction to be claimed should not be decided until the time of the first death. This is the latest point at which the decision can be made and the time when the surviving spouse, the heirs, and legal counsel have the best information about the relevant variables. This decision can be implemented by a formula clause which takes into account changes in circumstances or through use of a disclaimer clause in the decedent's will (Harl 1979a,b,c; Covey; Glasser).

Because the tax and credit rate structures are composed of a series of linear rates, the problem of equations (1)–(6) can be solved as a linear programming problem, assuming the number of years between deaths can be appropriately estimated using mean values from life expectancy tables. At first glance the stochastic dimension of the time of death would imply that a deterministic solution procedure such as linear programming would not be applicable to this problem. However, the problem only contains one stochastic event—the expected number of years between deaths—because the choice of an optimal marital deduction can be delayed until the death of the first spouse to die. To determine the sensitivity of the choice of the optimal marital deduction to expectations concerning the number of years between deaths (as determined by life expectancy and health of the survivor at the death of the first spouse to die), the number of years between deaths is parameterized in the empirical analyses from zero to twenty years. As will be shown later in the section on cost of choosing the wrong marital deduction, not knowing with certainty the time of death of the survivor does not detract from the usefulness of this model or the results generated.

Empirical Results

The specific combinations of parameters included in the analyses are summarized in table 1. For a combined estate size (husband and wife) of $500,000, wealth distributions of $200,000 owned by the first spouse to die and

Table 1. Combinations of Parameters Analyzed

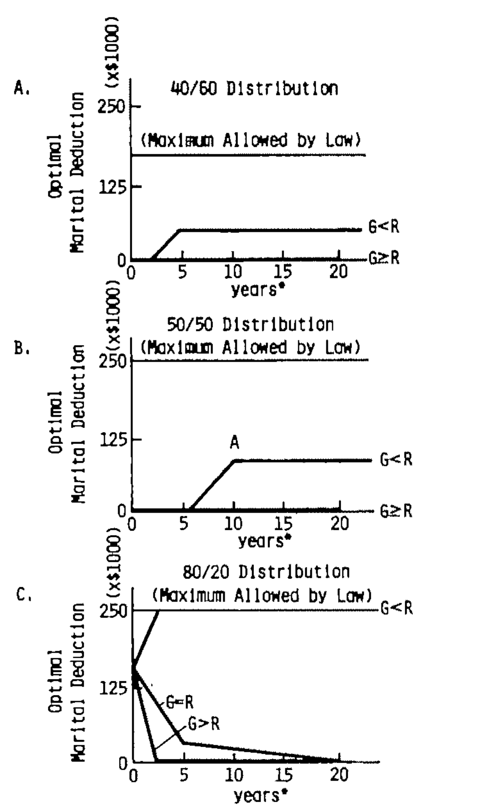
Combined Estate Size	Distribution between Spouses: Estate of First Spouse to Die (A_1)	Estate of Surviving Spouse (A_2)
	$	$
$ 500,000	200,000	300,000
	250,000	250,000
	400,000	100,000
$ 750,000	300,000	450,000
	375,000	375,000
	600,000	150,000
$1,000,000	200,000	800,000
	400,000	600,000
	500,000	500,000
	800,000	200,000

Note: Each distribution of property between spouses was run for three combinations of growth (G) and discount (R) rates ($G = 5\%$ and $R = 8\%$, $G = 8\%$ and $R = 5\%$, and $G = 8\%$ and $R = 8\%$). Each configuration of combined estate size, distribution between spouses, growth rate, and discount rate was then analyzed for values of N between zero and twenty years.

[7] The adjusted gross estate is the gross estate reduced by legal fees, court costs, and burial expenses. Because these settlement costs do not influence the size of the optimal marital deduction, they are ignored for the sake of simplicity.

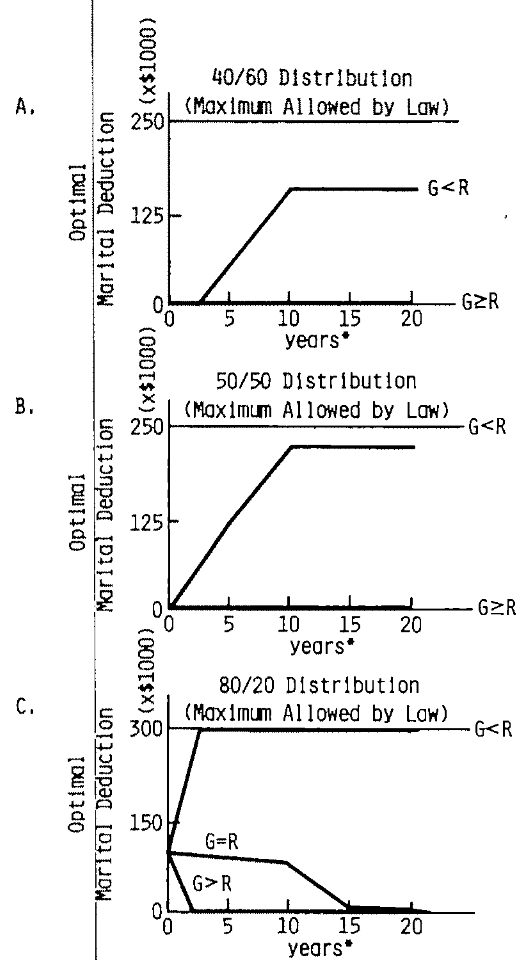
$300,000 owned by the second spouse; $250,000 owned by each; and $400,000 owned by the first spouse to die and $100,000 owned by the surviving spouse were analyzed. Each of these situations was evaluated for three combinations of growth (G) and discount (R) rates—$G = 5\%$ and $R = 8\%$, $G = 8\%$ and $R = 8\%$, and $G = 8\%$ and $R = 5\%$. These growth and discount rates were selected as representative of after-tax rates for a planning horizon of fifteen to twenty years. These rates may appear somewhat conservative for shorter planning horizons of, say, one or two years but were held constant so that comparisons can be made over planning horizons of different lengths. Additionally, it is the relative values of G and R that are important, not the absolute magnitudes of these rates. Finally, the expected number of years until the second death (N) was incremented from zero to twenty years. The results of these situations are graphically portrayed in figures 2A–2C.

With a combined estate size of $750,000, estate distributions between the decedent and surviving spouse of $300,000 and $450,000; $375,000 and $375,000; and $600,000 and $150,000, respectively, were analyzed, using the three combinations of growth and discount rates as above while incrementing N from zero to twenty years. The results of these combinations of parameters are presented in figures 3A to 3C. The last combined estate size selected for this analysis was $1,000,000 divided between the decedent and surviving spouse, respectively, as $200,000/$800,000; $400,000/$600,000; $500,000/$500,000; and $800,000/$200,000. Each of these analyses, again, was completed for the combinations of growth rates, discount rates, and expected number of years until the second death described above. The graphical results for this set of parameters are presented in figures 4A through 4D.



*Expected number of years until the second death are based on actuarial data.

Figure 2. $500,000 combined estates



*Expected number of years until the second death based on actuarial data.

Figure 3. $750,000 combined estates

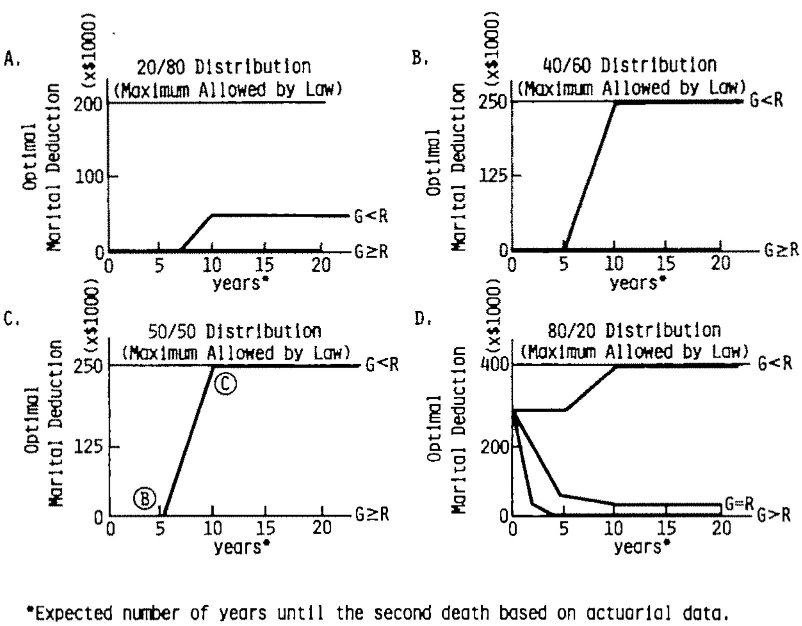


Figure 4. $1,000,000 combined estates

An Illustration

Table 2 illustrates the results for a combined estate of $500,000, with $200,000 included in the estate of the first spouse to die and $300,000 owned by the surviving spouse. The optimal marital deduction that minimizes the present value of the taxes at both deaths is presented for three selected values of expected life assuming an expected growth rate of 5% and discount rate of 8%.

If the surviving spouse is not expected to

Table 2. Numerical Example for a $500,000 Combined Estate

	Expected Number of Years until Second Death		
	<1	5	15
		$	
First death:			
Adjusted gross estate	200,000	200,000	200,000
Less: optimal marital deduction	0	50,000	51,370
Taxable estate	200,000	150,000	148,630
Tentative federal estate tax	54,800	38,800	38,389
Less: unified credit	38,000	38,000	38,000
Less: credit for state death taxes paid	1,200	400	389
Federal estate tax due	15,600	400	0
Present value of federal estate tax	15,600	400	0
Second death:			
Adjusted gross estate (at increased value)	300,000	446,696	730,462
Taxable estate	300,000	446,696	730,462
Tentative federal estate tax	87,800	137,677	241,071
Less: unified credit	38,000	47,000	47,000
Less: credit for state death taxes paid	3,600	8,600	19,587
Less: prior transfer credit	400	38	0
Federal estate tax due	45,800	82,259	174,484
Present value of federal estate tax	45,800	55,984	55,004
Present value of taxes at both deaths	61,400	56,384	55,004

Note: Expected growth rate = 5%; appropriate discount rate = 8%.

live out the year (leftmost column in table 2), the federal estate tax due at the first death is $15,600 based on an adjusted gross estate of $200,000, an optimal marital deduction of $0, and a taxable estate of $200,000. All property owned by the first spouse to die, net of estate taxes, passes to the surviving spouse in a legal life estate or life estate in trust and therefore does not increase the survivor's estate at the second death. At the surviving spouse's death, the federal estate tax due net of available credits is $45,800, based on an adjusted gross estate and taxable estate of $300,000. The present value of taxes at both deaths is $15,600 + $45,800 = $61,400. If a marital deduction is taken at the first death, the increase in tax due at the second death will more than offset the decrease in tax at the first death.

When the surviving spouse is expected to die five years after the first spouse (middle column, table 2), the federal estate tax due at the first death is $400 on a taxable estate of $150,000 (calculated as the adjusted gross estate of $200,000 less an optimal marital deduction of $50,000). The surviving spouse receives $50,000 in a life estate with a general power of appointment and $149,600 ($150,000 taxable estate less $400 tax) with only a life interest. After five years, the $300,000 adjusted gross estate of the surviving spouse and the $50,000 of marital deduction property have grown to $446,696, compounded annually at 5%. This adjusted gross estate of $446,696 produces a federal estate tax of $82,259, after available credits. The total present value of the taxes paid at both deaths is $56,384, which is the minimum possible (for $N = 5$ years, $G = 5\%$, and $R = 8\%$).

When the surviving spouse is expected to die fifteen years after the first spouse (right column, table 2), the optimal marital deduction is $51,370, which results in a taxable estate of $148,630. The credits available at the first death are just sufficient to offset the tentative federal estate tax, resulting in no tax due at the first death. The surviving spouse receives the $51,370 of marital deduction property outright and the remaining $148,630 with only a life interest. Fifteen years later the $300,000 of property the surviving spouse owns outright and the $51,370 of marital deduction property have grown to $730,462. This results in a federal estate tax due at the second death of $174,484, which, when discounted, results in a present value of $55,004. Because there was no tax paid at the first death, the total present value of taxes at both deaths is also $55,004.

Interpretation of Graphical Results

Figure 2A is constructed for a combined estate of $500,000, with $200,000 owned by the first spouse to die and $300,000 owned by the survivor. The expected number of years from the first death until the second death is graphed along the horizontal axis. The optimal marital deduction is graphed in thousands of dollars along the vertical axis. The maximum marital deduction allowed by law is $200,000 (the property owned by the decedent), and the minimum marital deduction is $0. There are three curves on this as well as the other graphs. One is for an expected growth rate (G) which is less than the discount rate (R); the second is for an expected growth rate larger than the discount rate; and the third is for an expected growth rate equal to the discount rate. For this estate size and distribution, if the growth rate is less than the discount rate and the surviving spouse is expected to live for less than two years, the optimal marital deduction which should be taken is zero dollars. With a zero marital deduction, all of the property of the first spouse to die is passed to the surviving spouse with only a life interest.

If the surviving spouse is expected to live for more than five years, the optimal marital deduction which should be taken is $51,370. A marital deduction of this size reduces the taxable estate of the decedent to $148,630 and increases the estate of the surviving spouse to $351,370. The unified credit of $38,000, available for deaths in 1979, and the credit for state death taxes paid of $389 are just sufficient to offset the tentative federal estate tax due at the first death. The surviving spouse would receive $51,370 outright and the remaining $148,630 with only a life interest.

The other two curves in figure 2A assume a growth rate greater than the discount rate and a growth rate equal to the discount rate. For these sets of parameters the two curves are superimposed upon the horizontal axis. That is, if the growth rate equals or exceeds the discount rate, the marital deduction that minimizes the present value of the taxes at both deaths is zero regardless of how long the surviving spouse is expected to live. The reason for an optimal marital deduction of $0 is that any marital deduction greater than zero increases the present value of the tax at the

second death by a larger amount than it reduces the present value of the tax at the first death. The graphs in figures 2, 3, and 4 can be interpreted in a similar manner.

Impact of Combined Estate Size

As the size of the combined estates increases from $500,000 to $750,000 to $1,000,000, the present value of the taxes paid at both deaths also increases, assuming a fixed proportionate distribution of property between spouses. If the growth rate is less than the discount rate and the surviving spouse is expected to live at least five years, the optimal marital deduction increases with increasing combined estate size. The optimal marital deduction is zero regardless of the combined estate size and distribution between spouses when the growth rate exceeds the discount rate and N exceeds five years. When the growth rate equals the discount rate, the optimal marital deduction is zero for all sizes of combined estates unless the first spouse to die owns a disproportionately large share of the estate (such as 80% in figs. 2C, 3C, and 4D). When the decedent owns 80% of the combined estates, the optimal marital deduction is always some value less than the optimal deduction for G less than R and greater than the optimal for G greater than R. The optimal marital deduction varies with the particular value of $G = R$ and with the number of years between deaths. For very low values of $G = R$ (2% or 3%), the optimal deduction is larger than that shown in figures 2C, 3C, and 4D. For values of $G = R$ above 8%, the optimal deduction is smaller than that shown in figures 2C, 3C, and 4D.

Impact of Estate Distribution

With a combined estate size of $500,000 (figs. 2A–2C), a growth rate smaller than the discount rate and N greater than ten years, the optimal marital deduction increases from $51,370 when the decedent owns $200,000 of the combined estate (fig. 2A) to $101,370 when the decedent owns $250,000 of the combined estate (fig. 2B). In both situations the decedent's taxable estate is reduced to $148,630, and the marital deduction taken is less than the maximum allowed by law. When the decedent owns $400,000 of a $500,000 combined estate (fig. 2C), the optimal marital deduction is constrained by the maximum allowed by law; if the decedent could, he or she would take an even larger marital deduction. If the upper limit on the marital deduction were not constrained by law, the optimal deduction would be $251,370, because this would reduce the decedent's taxable estate to $148,630.

If G is greater than R and N is greater than two years (again assuming a combined estate size of $500,000), the optimal marital deduction is zero for all distributions between spouses. This is also the case where the growth rate equals the discount rate except when the decedent owns 80% of the combined estate. In this latter situation the optimal marital deduction varies over time as shown in figure 2C.

The optimal marital deduction follows a similar pattern for combined estate sizes of $750,000 and $1,000,000, as summarized for the $500,000 estates. That is, if G is less than R and N is greater than ten years, the optimal marital deduction is the smaller of the maximum allowed by law and the amount which will result in no tax being paid at the first death through use of the credits. The optimal marital deduction is zero for G greater than R and N greater than four years for all estate sizes and distributional schemes considered. When the growth rate (G) equals the discount rate (R), the optimal marital deduction will be zero unless the decedent owns 80% of the combined estate. In this situation, the optimal marital deduction will fall somewhere in between the legal boundaries as shown in figures 3C and 4D.

Impact of Time

The passage of time (in terms of the expected life of the surviving spouse) affects the optimal marital deduction in two ways. For the first ten years between deaths, a prior transfer credit is available at the second death for taxes paid at the first death. This makes paying taxes at the first death relatively more attractive because it generates an additional credit which can be employed at the second death. The second impact is the compounding effect that time has on both the discount factor and the growth factor.

Because of these two effects of time, the optimal marital deduction may vary a great deal during the first ten years between deaths depending upon the values for the other parameters. As N increases beyond ten years, the optimal deduction remains constant except in the cases where $G = R$ and the decedent

owns 80% of the combined estate (figs. 2C, 3C, and 4D). For example, with a combined estate of $1,000,000 distributed equally between spouses and G less than R (fig. 4C), the optimal marital deduction is zero for N between zero and five years. The optimal deduction increases from zero to the maximum allowed by law as N increases from five to ten years. Then, for all values of N greater than ten years, the optimal marital deduction remains at the maximum allowed by law of $250,000. Similar results are obtained for the other estate sizes and distributions.

Impact of the Discount Rate and Rate of Growth

Of the variables which influence the size of the optimal marital deduction (combined estate size, distribution between spouses, expected years between deaths, growth rate and discount rate), the growth rate (G) and the discount rate (R) are the most crucial. With the exception of the case where the decedent owns 80% of the combined estate and G equals R, it is the relationship of G to R and not their absolute values which is the most important in determining the optimal marital deduction. If the growth rate is larger than the discount rate and N exceeds four years, the optimal marital deduction is zero under all combined estate sizes and all interspousal distributional schemes evaluated. If the growth rate is smaller than the discount rate and N exceeds ten years, the optimal marital deduction is the maximum allowed by law or the amount which just reduces the federal estate tax liability at the death of the first spouse to zero, whichever is smaller. If the growth rate equals the discount rate, the optimal marital deduction is zero under all combined estate sizes unless the spouse who dies first owns a disproportionately large share of the estate (such as 80% in this analysis). In this situation the optimal marital deduction falls somewhere between the optimal deduction for G less than R and the optimal for G greater than R. Just where the optimal deduction falls depends on the absolute value of $G = R$.

Cost of Choosing the Wrong Marital Deduction

For any point on the curves of figures 2, 3, and 4, graphs such as those presented in figures 5, 6, and 7 can be constructed to indicate the cost

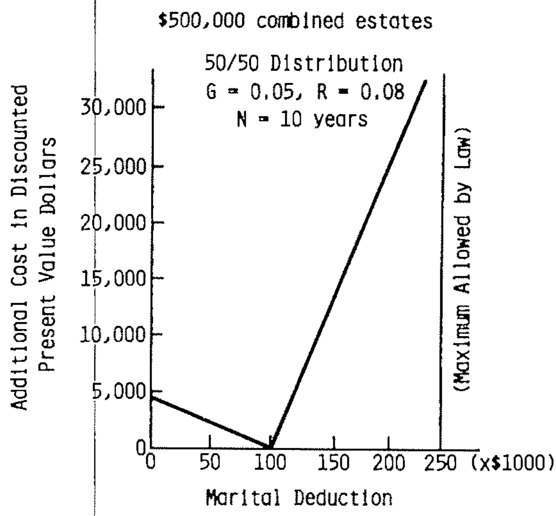


Figure 5. Cost of choosing the wrong marital deduction (point A on figure 2B)

of choosing the wrong marital deduction. Points selected for further analysis are A on figure 2B (shown in fig. 5) and B and C on figure 4C (figs. 6 and 7, respectively).

On each of the graphs in figures 5 through 7, the horizontal axis measures the amount of marital deduction actually taken. The vertical axis measures the additional cost in discounted present value dollars of the taxes paid at both deaths from taking a marital deduction other than the optimal. These graphs show the cost of choosing the wrong marital deduction, or, conversely, the value of using the optimal as opposed to some other marital deduction such as the maximum allowed by law.

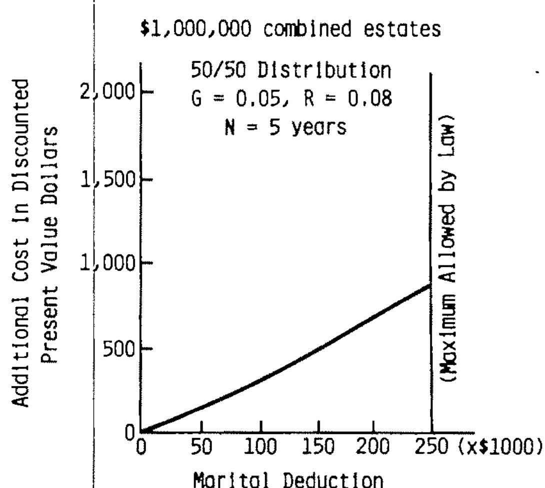


Figure 6. Cost of choosing the wrong marital deduction (point B on figure 4C)

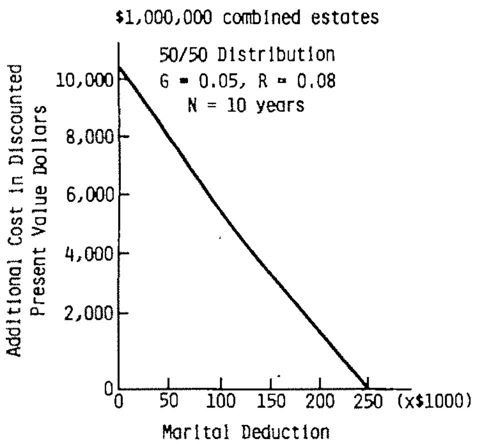


Figure 7. Cost of choosing the wrong marital deduction (point C on figure 4C)

With a combined estate of $500,000, a growth rate less than the discount rate and the expected life of the surviving spouse equal to ten years, the optimal marital deduction is $101,370 (fig. 2B). If, instead, a marital deduction of only $50,000 is taken, the present value of the taxes paid at both deaths is increased by $2,388 over the minimum tax liability (fig. 5). If a marital deduction of zero is taken, the present value of taxes is increased by $5,336. On the other hand, a $150,000 marital deduction results in an increase of $12,050 in the present value of the taxes paid at both deaths. If the maximum marital deduction allowed by law of $250,000 is taken, the present value of taxes paid increases by $37,188. The reason it is more costly to over-qualify rather than under-qualify for the marital deduction is that with over-qualification, full use is not being made of the credits available at the first death.

With a combined estate of $1,000,000 owned equally by the spouses, a growth rate less than the discount rate and the expected time between deaths of five years (fig. 6), the optimal marital deduction under these circumstances is zero dollars (fig. 4C). If the actual marital deduction taken was $50,000, the present value of taxes would increase by $87 (fig. 6). If the maximum marital deduction allowed by law is taken, the cost of making this mistake is $694.

For the same set of circumstances as described above, with the exception of the time between deaths of ten rather than five years (fig. 7), the optimal marital deduction is $250,000 (fig. 4C). If the actual marital deduction taken is $200,000, the additional present value of taxes is $1992 (fig. 7). If no marital deduction is taken, the additional cost in terms of taxes paid is $10,502.

Note that with this estate size and distribution and an expected life of five years (fig. 6), missing the optimal marital deduction by $250,000 increases the present value of taxes by only $694 (from $198,927 to $199,621). However, with an expected life of ten years (fig. 7), the cost of a mistake in taking the wrong marital deduction is considerably larger. The present value of taxes increases by $10,502, from $188,522 at the optimal level to $199,024, when no marital deduction is taken. The longer the expected life of the surviving spouse, the more costly is a mistake in taking the wrong marital deduction. Thus, in situations such as described here, it is more important to choose the optimal marital deduction when the expected life of the surviving spouse is ten years than when the expected life is only five years. This is a direct result of the compounding effects of time on the expected growth rate and discount rate and the influence of these parameters on the optimal marital deduction.

As noted earlier, at the time the decision as to the optimal marital deduction must be made, the one variable which cannot be ascertained with certainty is the expected remaining life of the surviving spouse. To be sure, the death of the surviving spouse can be estimated from actuarial data as has been done in this analysis. Or if the health of the surviving spouse is abnormally poor for his or her age, a subjective estimate of life expectancy may be made based upon the state of health. However, as shown in figures 6 and 7, taking any size marital deduction, even the maximum allowed by law, does not result in a very costly error if the surviving spouse dies within ten years of the decedent. If the surviving spouse dies more than ten years after the decedent, the cost of taking the wrong marital deduction is much greater. However, the optimal marital deduction remains constant (assuming a particular estate size, distribution, growth, and discount rates) if the surviving spouse dies ten or more years after the decedent. Therefore, even though the cost of making a mistake becomes larger as the time between deaths increases beyond ten years, any deviation between the actual date of death and the expected date of death results in no error in the choice of the optimal marital deduction.

Conclusions

Only selected combined estate sizes and distributional schemes have been analyzed, but due to the symmetry of the analysis—both spouses face the same unified federal gift and estate tax rate schedule and the same credit schedules—the results presented here can be generalized for estates of all sizes.[8] These generalizations are as follows:

(*a*) If the expected growth rate is less than the appropriate discount rate, the optimal marital deduction will be the smaller of the maximum allowed by law, or the marital deduction which makes full use of all credits available and results in no federal estate tax at the first death.

(*b*) If the expected growth rate is greater than the appropriate discount rate, the marital deduction which should be taken is zero.

(*c*) If the expected growth rate equals the discount rate and if the first spouse to die does not own a disproportionately large share of the combined estate, the optimal marital deduction that should be taken is zero. If the first spouse to die does own a disproportionately large share of the combined estate, it may be necessary to perform an analysis similar to the one presented here to determine the optimal marital deduction.

The one variable the estate planner cannot ascertain with certainty is the expected life of the surviving spouse. The stochastic nature of this variable may result in some error if the above generalizations are used. However, drawing values for the expected life variable from actuarial tables or from subjective estimates of state of health produces a marital deduction amount that is, in a high proportion of instances, closer to the optimal level than the common practice of claiming the maximum allowed by law or the maximum marital deduction which will just reduce the tax liability of the decedent to zero, as is the typical practice.

The choice of the optimal marital deduction is only one example of the opportunity to apply economic concepts and optimization procedures in estate planning. Additional applications include the optimal funding of the marital deduction, the optimal distribution of property ownership prior to the death of either spouse, the optimal gifting program among spouses and heirs and the interactions between the marital deduction at death, lifetime gifts, installment payment of tax, special use valuation and the income tax basis of estate property. Further research to evaluate these issues is ongoing.

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[8] This symmetry holds only if the tax laws do not change during the period between deaths.

References

Allington, Thomas B. "How Interspousal Gifts, the Marital Deduction Shape Estate Taxes on Successive Estates." *J. Taxation* 48(1978):284–88.

Barnes, Scott Y. "New Tax Court Decisions Broaden Estate Planning Potential of Marital Deduction." *J. Taxation* 45(1976):292–95.

Barnett, B. "After-death Estate Planning." *Tax Advisor* 1(1970):21–26, 105–11, 181–97.

Boehlje, Michael, and L. M. Eisgruber. "Strategies for the Creation and Transfer of the Farm Estate." *Amer. J. Agr. Econ.* 54(1972):461–72.

Brode, George, Jr. "Not Maximizing the Marital Deduction in Certain Estates May Produce Higher Savings." *J. Taxation* 48(1978):148–52.

Case, Stephen S. "Post-Mortem Estate Planning is Complex but Offers Valuable Tax Savings Opportunities." *J. Taxation* 42(1973):78–80.

Covey, Richard B. *The Marital Deduction and the Use of Formula Provisions.* New York: Bobbs-Merrill Co., 1978.

Glasser, G. K. "Disclaiming an Interest in Property under New Rules: . . ." *Estate Planning* 4(1977):204–06.

Harl, Neil E. *Farm Estate and Business Planning*, 5th ed. Skokie, Ill.: Century Communications, 1979a.

———. *Farm Estate and Business Planning: (Annotated Course Materials)*. Minneapolis, Minn.: National Practice Inst., 1979b.

———. *Where There's a Will.* Iowa State University Coop. Extens. Serv. PM-540, rev. July 1979c.

———. "How to Use the Marital Deduction to Minimize Estate Taxes at Both Deaths." *Successful Estate Planning Ideas and Methods.* Englewood Cliffs, N.J.: Prentice-Hall, 1977.

Harl, Neil E., and M. Boehlje. "An Economic Model for Estate Management Planning." *Trusts and Estates*, pp. 208–37, April 1978.

Internal Revenue Code of 1954 (IRC).

Levi, Donald R., and J. K. Allwood. "Legal-Economic Models As a Tool for Optimizing Intergenerational Property Transfers." *Amer. J. Agr. Econ.* 51(1969): 1393–98.

Tax Reform Act of 1976 (H. R. 10612, 94th Congress, Public Law 94-455).

Thomas, Don A., R. A. Esperti, and M. M. Katz. "New Variable Marital Deduction Technique Eliminates Uncertainty in Estate Plans." *J. Taxation*, 47(1977):194–97.

Attitudes toward Risk: Experimental Measurement In Rural India

Hans P. Binswanger

Attitudes toward risk were measured in 240 households using two methods: an interview method eliciting certainty equivalents and an experimental gambling approach with real payoffs which, at their maximum, exceeded monthly incomes of unskilled laborers. The interview method is subject to interviewer bias and its results were totally inconsistent with the experimental measures of risk aversion. Experimental measures indicate that, at high payoff levels, virtually all individuals are moderately risk-averse with little variation according to personal characteristics. Wealth tends to reduce risk aversion slightly, but its effect is not statistically significant.

Key words: India, psychological experiments, risk aversion, semi-arid tropics.

The research reported here was carried out in the semi-arid, tropical areas of India, characterized by high climatic risk for agriculture. It was initiated to determine whether differences in behavior between farmers of different wealth levels are the consequence of different attitudes towards risk or of different constraint sets such as limitations on credit or on access to modern inputs. This question is of considerable policy importance because policy presumably can affect credit and other constraints faced by low income farmers more easily than their attitudes toward risk. The basic approach is experimental. It measures attitudes by observing the reactions of individuals to a set of actual one-period gambles. It must be recognized that extrapolating the findings of such an approach to real farm decisions may face theoretical challenges.[1]

Earlier experimental work on measurements of attitudes toward risk was carried out primarily by experimental psychologists and is reviewed by Luce and Suppes. Where actual gambles were involved, payoffs and sample sizes were small. In this study, payoffs varied from very low levels to levels exceeding the monthly incomes of unskilled rural laborers. The total sample size was 330.

Agricultural economists have measured parameters of utility functions by simulated gambling situations rather than actual ones. Officer and Halter, O'Mara, and Dillon and Scandizzo used approaches based on utility theory and elicitation of certainty equivalents. Kennedy, instead, used a method based on focus loss. Only Dillon and Scandizzo used simulated farming problems rather than pure simulated gambles.

The Experimental Sequence

The experimental method based on one-period gambles was developed after results of a survey using the Dillon-Scandizzo approach suggested that their method was subject to interviewer biases (fourth section).[2] To overcome

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[1] Masson and Roumasset (1978b) point out that under fairly restrictive assumptions, a utility function in "one-period money" may be viewed as an indirect utility function that reflects the interaction of a lifetime utility function of consumption with borrowing and lending opportunities. An individual who is risk-neutral with respect to utility function in lifetime income may exhibit an apparently risk-averse indirect utility function for one-period money because of capital market imperfections, and therefore the attempt to separate attitudes from constraints may be impossible using one-period gambles.

[2] The author is personally indebted to John Dillon and Pasquale Scandizzo for encouraging him to start work on risk aversion with large samples. He is indebted also to J. G. Ryan and Matthias von Oppen for later encouraging a shift to experimental methods.

moral problems confronting low income people involved in gambling, the gambling was limited so that the worst possible outcome was a zero gain, and it thus involved gifts to the respondents. Because many respondents were illiterate, the experiment had to be simple. Also, because farming decisions are often taken on an annual or crop-cycle basis and in consultation with relatives and friends, the experiment was designed to allow long periods for reflection and opportunities for consultation.

Only minimal theoretical commitments were to be made at the outset. The set of choices should be ranked as more or less risky in a unique way, almost regardless of the definition of risk one might want to adopt. (For a review of problems of defining risk, see Roumasset 1978a.) The subjects were not to be confronted with any budget constraints that would rule out certain choices. One cannot, in measuring pure attitudes to risk, propose games to individuals for which the worst possible loss exceeds their current cash holdings. If one does, he may measure the impact of a cash- or budget-constraint rather than the pure attitudes towards risk (Masson, Lipton). As far as possible, respondents should perceive the same probabilities; therefore, the game was based on coin tosses.

Table 1 explains the basic method. Several days ahead of any given game, individuals were given forms (which they could keep) with the numbers of panel A on table 1. They had to choose from alternatives O to F. Once they chose, a coin was tossed and they got the left-hand amounts if heads came up or the right-hand amount if tails came up. An individual who chose O simply got Rs.50; i.e., participation in the game resulted in an automatic and sure increase in wealth by Rs.50. An individual choosing C received Rs.30 on head and Rs.150 on tail. By not choosing O he stood to lose Rs.20, but could gain Rs.100. Compared to B, which was more relevant, the potential losses and gains in going to C were Rs.10 and Rs.30, respectively. Finally, by choosing F the individual received either no money or Rs.200; F had the same expected return as E, but a higher variance, so only a risk-neutral or risk-preferring individual would make the step from E to F.

At the simplest level the choice of any alternative O to F classified the individuals into a risk aversion class to which a name was given to simplify discussion. Interpreted in the framework of expected return-variance analysis (which is useful when decision makers are confronted with normally distributed outcomes), the game consisted of offering individuals a set of alternatives within which higher expected returns could only be "purchased" at the cost of higher variance (or standard deviation), and this tradeoff could be measured by the slope Z in table 1. Interpreted in a utility framework, risk aversion could be measured by partial risk aversion S, which is fixed regardless of the level of payoff (Menezes and Hanson; Zeckhauser and Keeler).[3] To each risk aversion class corresponded an interval of partial risk aversion S.

[3] It is defined on a utility function U in terms of certain wealth W as follows: let M be the certainty equivalent of a new prospect and evaluate derivatives at $W + M$; then,

$$S(W + M) = -MU''(W + M)/U'(W + M),$$

Table 1. The Payoffs and Corresponding Risk Classification

Choice	Panel A: Heads—Low Payoff	Panel A: Tails—High Payoff	Risk Aversion Class	S Approximate Partial Risk Aversion Coefficient[a]	$Z = \frac{\Delta E^b}{\Delta SE}$
O	50	50	Extreme	∞ to 7.51	1 to 0.80
A	45	95	Severe	7.51 to 1.74	0.8 to 0.66
B	40	120	Intermediate	1.74 to .812	0.66 to 0.50
D^*	35	125	Inefficient		
C	30	150	Moderate	.812 to .316	0.50 to 0.33
D	20	160	Inefficient		
E	10	190	Slight-to-neutral	.316 to 0	0.33 to 0.00
F	0	200	Neutral-to-negative	0 to $-\infty$	0 to $-\infty$

[a] For reasons that are explained in Binswanger (1978c), a constant partial risk-aversion function on gains and losses was used to approximate S for the games. See footnote 4 for more details.

[b] Z is the trade-off between expected returns and standard deviation of two games.

In the experimental sequence (table 2) the individual was not presented immediately with the alternatives of table 2, called 50-rupees game; instead he went through a sequence of games and hypothetical questions at various game levels. All game levels were derived from the 50-rupees game by multiplying all amounts by a constant, which is 1/100, 1/10, and 10 for the 1/2-rupee, 5-rupee, and the 500-rupee game levels, respectively. The sequence started with five games at the Rs.0.50 level to teach participants the rules of the game and to convince them that they would receive the money when promised. To help illiterate people, the payoff structure was shown as a photograph with the sums of money to be received indicated by coins placed in each field. The photographs were handed out to each player and left with them through the entire 5- to 6-week period of the experiment.

The study was carried out in the 240 rural households included in the village level studies of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Hyderabad, India. (For more details, see Jodha, Asokan, Ryan; Binswanger and Jodha.) These studies are located in the semiarid tropical tracts of Maharashtra and Andhra Pradesh, some of the poorer regions of India.

The average physical wealth of the households, approximately Rs.22,000 (US $2,750), is very low by international standards. But there were large variations in wealth in the sample, as indicated by a coefficient of variation of physical wealth of 137%. The average schooling level was only 2.6 years but had a coefficient of variation of 120%. Being a random sample of the entire population engaged in agriculture as laborers or farmers, variation in other personal characteristics was also large.

Up to the Rs.5 level, the sequence was played with all 240 household heads of the sample (of which 20 were women), although temporary absences from villages made some of the sequences incomplete. In three of the six villages (118 households) the full sequence was played. In addition, in two villages the most important dependent female of the household, usually the wife, was also included in the experiment up to the Rs.5 level (the

where U' and U'' are the first and second derivatives of the utility function. Other utility based measures of risk aversion are discussed in Binswanger (1978a) but S was the most convenient one.

Table 2. Sequence of Games and Hypothetical Questions

Game Number	Minimum Delay Since Last Event[a]	Game Level (Rs.)	Real or Hypothetical	Village[b]
1	First Day	0.50	Real	All
2	One day	0.50	Real	All
3	One day	0.50	Real	All
4	One day	0.50	Real	All
5	One day	0.50	Real	All
6	Two weeks	50.00	Hypothetical	Shirapur excluded
7	Same day	5.00	Real	All
	Same day	Hand out Rs.5.00 for next day game		
8	One day	50.00	Hypothetical	Shirapur excluded
9	Same day	5.00	Real	All
10	Same day	5.00	Hypothetical	All
11	Two Weeks	500.00	Hypothetical	Shirapur
12	Same day	50.00	Real	Kanzara
13	Same day	50.00	Hypothetical	Aurepalle only
14	Same day	50.00	Hypothetical	Kalman Kinkheda
15	Same day	5.00	Hypothetical	Dokur only
16	Two weeks	500.00	Hypothetical	Shirapur Kanzara
17	Same day	50.00	Hypothetical	Aurepalle only

[a] In many cases these minimum delays were exceeded by a few days.
[b] There are six villages, two each in three districts: Sholapur district—Shirapur and Kalman; Akola district—Kanzara and Kinkheda; Mahboobnagar district—Dokur and Aurepalli. Each village contains a panel of forty households and households heads were included in all villages. In Kinkheda and Dokur the most important dependent female in each household was also included in the experiment in addition to the head of household who, on occasion, was female.

dependent female sample). In five villages a nonrandom sample of the three "most progressive" farmers of the village was added (the progressive farmer sample). Progressive farmers are early adopters of new techniques. They were identified by the resident investigators on the basis of the investigator's knowledge of the villages. For all games except at the Rs.0.50 level, respondents' choices were ascertained by a first investigator and verified with the respondent by a second investigator. In about 250 games, including all the 50-rupee games, the author was the second investigator. In only two cases did the respondent change his mind. It was clear that the respondents enjoyed the game. No attempt was made to isolate the respondents from their peers except for the second verification. Agricultural decisions are also observable in the village context and their outcomes are known to all.

Reliability Tests

The first test was concerned with whether behavior with gift money differs from behavior with own money. (A fuller account of these tests is given in Binswanger 1978c.) To pretest the method, ten individuals were at one stage asked to play the game with their own money, and nine out of ten chose the same alternative as in the immediately preceding game, while one respondent became more risk-averse. With the household heads of the full sample a different test was carried out: one day prior to game 9, Rs.5 were given to the respondents and they had the choice not to come to play game 9 (such a choice was interpreted as the riskless choice O). If they chose to play game 9, they had to pay back any losses relative to the Rs.5 of that bet. If after gift money was in their possession for one day the respondents considered it their "own," comparison of the risk aversion distribution of game 7 and game 9 is a test of differences in behavior with gift and one's own money. A chi-square test of differences between games 7 and 9 in the distribution of choices over the alternatives was not significant at 0.05 level.

The second test concerned the usability of answers to hypothetical games included in the sequence. It was hoped that after playing the full sequence up to the Rs.50 level, individuals would acquire the introspective ability to tell how they would play at the Rs.500 level. One could then use the hypothetical answers as if they were real choices. Hypothetical games 6, 8, and 13 at the Rs.50 level were introduced in two villages (Aurepalle and Kanzara) for comparison with the real 50-rupee game. Chi-square tests at the 0.5 level showed that, before playing the 50-rupee game, people believed that they would act either more aversely or less aversely to risk than they actually did in the real game 12, i.e., the risk-aversion distribution was far more dispersed in the early hypothetical answers than in the real game. However, once the 50-rupee game was played, there was no statistically significant difference between the real choices in game 12 and the hypothetical answers to games 13 or 17. The data also indicate that the ability of respondents to predict their actual behavior in a hypothetical question increases as the game sequence proceeds, even before the 50-rupee game is played. Therefore, from this point on, the hypothetical 500-rupee game number 16 will be interpreted as if it really had been played, albeit with caution.

The third test was to investigate whether individuals, when confronted with a game such as in table 1, had an automatic tendency toward alternatives in the center of the distribution. Table 1 contains two risk inefficient alternatives D and D^*, which are derived from C and F, respectively, and have the same means but higher variance. No risk-averse individual should choose these alternatives, and they were introduced precisely to test whether people could detect stochastic dominance in this simple context.

Note that in a game structure containing D but not D^*, alternative C is the most central alternative and, under the "central tendency hypothesis," should be the most preferred one. On the other hand, if D is deleted from table 1, alternative D^* becomes the most central one. In three villages half the respondents were given the game structure containing the alternative D, while the other half were given the game structure containing D^*. It was found that for both games 9 and 12, the frequency distributions associated with the two game structures could not be distinguished statistically.

There were three potential learning effects in the experiment. The first one concerned the ability to know risk preferences when the participant is faced with a hypothetical question without making an actual decision, which was discussed above. A second potential learning

effect was revisions of personal probabilities of heads and tails in coin tosses, which will be discussed later. A third learning effect concerned the rules of the games. How many games did one have to play till one was sufficiently familiar with the rules? A chi-square test of the differences in risk aversion distribution was performed between the successive 0.5-rupee game; these tests were not significant, although there was a trend toward less risk aversion as the games proceeded. Respondents thus appeared to familiarize themselves quickly with the rules.

When using the Dillon and Scandizzo interview method (to be discussed in a later section of this paper), two investigators were identified who tended to elicit substantially different certainty equivalents while interviewing the same respondents. These investigators were assigned to two different subsamples—forty respondents each, twenty in each of two villages—for the entire game sequence. No statistically significant differences could be found between the risk-aversion distributions of the two subsamples and investigator bias appeared to be less of a problem using the game method than with interview methods.

The Main Experimental Results

The risk-aversion distributions corresponding to different game levels are given in table 3, in the first panel for those villages where the game was played up to the 50-rupee level (with a hypothetical answer at the 500-rupee level) and in the second panel for all the households, including those where the game was played only up to the 5-rupee level. Observe that at low levels of the game the distribution was fairly evenly spread across the four classes of intermediate risk aversion to risk neutrality. As the game level rose, the distribution shifted to the right and became more peaked, i.e., risk aversion increased.

Consider the slight-to-neutral and neutral-

Table 3. The Effect of Payoff Size on Distribution of Risk Aversion

Payoff Level and Game Number	Extreme	Severe	Intermediate	Moderate	Slight-to Neutral	Neutral to Negative	Inefficient	Sample Size
	Household Heads: Shirapur, Kanzara, Aurepalle							
A 0.50 No. 2	1.7	5.9	28.5	20.2	15.1	18.5	10.1	119
B 0.50 No. 4 + 5	1.7	8.1	14.5	29.3	21.3	16.6	8.5	235
C 5 No. 7	0.9	8.5	25.6	36.8	12.0	8.5	7.7	117
D 50 No. 12	2.5	5.1	34.8	39.8	6.8	1.7	9.3	118
E 500 H No. 16	2.5	13.6	51.7	28.8	0	0.9	2.5	118
	All Household Heads							
F 0.50 Games 2 + 3	1.7	7.6	18.5	22.7	17.1	18.7	13.7	475
G 0.50 Games 4 + 5	0.9	8.2	12.9	27.5	22.8	18.4	8.3	473
H 5.00 Games 7 + 9	0.8	8.1	23.8	36.5	11.9	9.8	9.1	471

Distributions tested	χ^2	*df*	χ^2 0.05
A vs. *C* vs. *D* vs. *E*	85.68	18	28.87
C vs. *D* vs. *E*	48.49	12	21.03
A vs. *C*	11.91	6	12.59
B vs. *D*	44.22	6	12.59
D vs. *E*	23.46	6	12.59
A vs. *B*	13.17	6	12.59
F vs. *G*	16.30	6	12.59
G vs. *H*	50.02	6	12.59

to-preferred classes: at the Rs.0.50 level, the percentage in each of these classes is around 15 to 20, and it falls monotonically to near zero as the payoff level rises to Rs.500. In the moderate risk-aversion class, we initially find around 20% of the individuals. This percentage first rises at the Rs.5 and Rs.50 levels because people enter this class when leaving the lower risk-aversion classes. But between the Rs.50 and Rs.500 level, the number of entrants from lower risk aversion is lower than the number of individuals who become more risk-averse and the frequency in this class declines. The intermediate risk-aversion class starts out with 28.5% of individuals in game 2 at the Rs.0.50 level. As that game is repeated people prefer to play at higher stakes. But as the payoff level rises again, more people enter this class from the lower risk-aversion classes and at the Rs.500 level more than 50% of individuals are concentrated in this single class. The 500-rupee game corresponded to payoffs in the order of substantial fertilizer investments for these households, and many were too poor to undertake them. For some households it even exceeded net wealth.

The extreme and severe risk-aversion classes together contained less than 10% of the individuals for all levels except the Rs.500 level, in which the percentage rose to 15. There appears to be an upper barrier to risk aversion that is exceeded only very slowly at high stakes.

In any given game, around 10% of individuals chose one of the inefficient alternatives. This is clearly lower than the percentage of individuals who would choose it on a random basis. Consider game 12. Inefficient alternatives exist between the intermediate and moderate and the moderate and slight-to-neutral alternatives. These three classes and the inefficient ones contain 90.7% of individuals. If people fell into the two inefficient and three efficient classes at random, the two inefficient classes would contain at the very least one-fifth of the 90.7% observations, i.e., 18.1%, but the actual percentage was 9.3.

Who chooses inefficiently varies much across games. Two hundred and eighty seven individuals played all the games from 1 to 9. Of those, ninety-four (or 33%) chose one of the inefficient alternatives at least once, i.e., they did not recognize that they were stochastically dominated, or did not care about it at least once.

The evidence can thus be summarized as follows. For individuals with initially low risk aversion, it tends to rise fairly rapidly as game levels start to rise beyond trivial levels. For individuals who initially have intermediate to moderate levels of risk aversion, the level increases slowly or remains fairly constant as game levels rise. As can be seen from the chi-square tests (bottom of table 3), these trends are statistically significant and evident in both the reduced sample and the full sample of households.

Interpreted in the utility framework, the evidence suggests that all but one of 118 individuals have nonlinear, risk-averse utility functions, which exhibit increasing partial risk aversion.[4] It has been shown elsewhere (Binswanger 1978c) that the results also imply decreasing absolute risk aversion. Relative risk aversion first decreases and then increases.

Interviews versus Gambling Experiments

The most immediately comparable study to the present one (and the one which initially inspired it) is by Dillon and Scandizzo for a semi-arid tropical region of Brazil. It had a sample size of 103 farmers. Prior to the gambling experiment, the author executed a similar interview-based survey in the Indian SAT villages. In this section the author describes the problems encountered with the Dillon-Scandizzo method and then compares the results of the two surveys with each other as well as with the experimental results.

Dillon and Scandizzo describe their method as follows: "The farmer's risk attitudes were appraised via their choices between hypothetical but realistic farm alternatives involving risky versus sure outcomes. These questions

[4] To obtain unique measures of partial risk aversion associated with the indifference points between two alternatives, a constant partial risk-aversion function (CPR) of the form $U = (1 - S)M^{1-S}$ was used. Given the evidence of increasing partial risk aversion one might object that an increasing partial risk-aversion function (ICPRA) should have been used (Binswanger 1978b). However, the partial risk-aversion coefficient for any indifference point will then not be unique but will depend on the rate at which partial risk-aversion increases, i.e., on the choice paths across the game scale. Therefore, partial risk-aversion coefficients were computed for each indifference point at each game scale and for each feasible choice path given a smooth ICPRA utility function. Because income varies more across game scales than within each game scale, S values associated with these ICPRA differed by less than 2% from those associated with the CPR functions, except for the indifference point between alternative O and A, where the largest difference was 15%. Because few respondents chose alternative O to A, the results of this paper would not be substantially affected by using S values from an ICPRA function.

form the basis of our empirical analysis and were geared to finding the certainty equivalents of risky prospects involving stated probabilities. Two types of risky prospects were used, yielding two subsets of responses for each group of farmers. The first type involved only payoffs above household subsistence requirements. In these, while the level of total income was at risk, subsistence was assured. The second type of risky prospect included the possibility of not producing enough to meet subsistence requirements. Both types of risky prospect involved only two possible outcomes whose probabilities were specified as invariant frequencies" (Dillon and Scandizzo, p. 427). These frequencies were 0.75 ("3 years out of 4") for the "good" outcome and 0.25 ("1 year out of 4") for the "bad" outcome.

In the Indian study the "good" outcome and the "bad" outcome of the uncertain prospect are fixed so that the expected value of the uncertain prospect was one-half of subsistence income and twice the subsistence income, respectively. Subsistence income previously had been established for each household individually by asking householders, item by item, their minimum annual requirement of all food and clothing. Subsistence income ranged from Rs.462 to Rs.14,117. The certainty equivalent of the prospect was then found by varying the certain income until indifference with the uncertain prospect was attained.

When analyzing the results of the Indian survey, several problems and inconsistencies were encountered. The most serious was that in two neighboring villages, Shirapur and Kalman, the distributions of risk-aversion coefficients differed sharply. For table 4, the elicited survey results were converted into partial risk-aversion coefficients using a constant partial risk-aversion function (see footnote 4) and grouped into the same classes as those of the experimental study, except that the intermediate and moderate classes were pooled. The second and third line of table 4 (Shirapur First and Kalman First) compare the results for the first survey carried out by investigators A and B, respectively. Shirapur appears to be more risk-averse and the difference is statistically significant.

The villages were then resurveyed, switching investigators, and the results are given in the line 1 and line 4 of table 4. Comparison of line 1 with line 2 and line 3 with line 4 clearly shows that in each village investigator B classifies respondents as more risk-averse than investigator A, and these differences are statistically significant. This cannot be caused by the time lag of more than a month between interviews because the time sequence of investigators was reversed between the villages. Thus, the interview technique is subject to severe interviewer bias. Resurveys also were carried out in other villages. By analyzing all resurvey results, it was found that in more than 20% of the cases individuals were reclassified radically between extreme risk aversion and neutrality or negative and positive risk aversion. In the game results, such radical reclassification in successive games at the same level is rare (Binswanger 1978a).

Table 5, lines A and B, show the distributions for the 50- and 500-rupee games, while lines C and D show the India interview results

Table 4. Survey Results in Shirapur and Kalman

Risk Aversion Distributions Obtained by Different Investigators in Two Villages[a]

Village and Survey	Investigator	Survey or Resurvey	Risk-Aversion Class: Extreme	Severe	Intermediate or Moderate	Slight or Neutral	Negative	Number of Observations
Shirapur (second)	A	Resurvey	10	9	4	5	5	33
Shirapur (first)	B	Survey	20	10	3	0	0	33
Kalman (first)	A	Survey	4	5	5	11	4	29
Kalman (second)	B	Resurvey	11	12	1	2	3	29

Relevant chi-square tests, all significant at better than 0.01 level.
[a] In absolute numbers.

Table 5. Comparison of Interview-Based and Experimentally Based Distribution of Risk Aversion

	Extreme	Severe	Intermediate or Moderate	Slight or Neutral	Negative	Inefficient	No. of Observations
			India				
A. Game no. 12; Rs. 50	2.5	5.1	74.6	6.8	1.7	9.3	118
B. Game no. 16; Rs. 500	2.5	8.2	85.9	0	0.9	2.5	118
C. Interview Subsistence-at-risk[a]	27.0	34.3	18.0	6.3	14.4	n. appl.	222
D. Interview Subsistence-assured[a]	18.2	43.6	15.5	9.1	13.6	n. appl.	220
			Dillon and Scandizzo's Interview Based Results from Brazil[b]				
E. Subsistence-at-risk[a]	26.2	57.3		0	16.5	n. appl.	103
F. Subsistence-assured[a]	32.0	32.1		8.7	27.2	n. appl.	103

(A) vs. (C) or (A) vs. (D) Chi-square > 95; $\chi^2(4,0.05) = 9.49$

Note: Comparisons are in percentage of number of observations.

[a] Subsistence-at-risk and subsistence-assured refer to two different payoff levels. In the first, the "bad" outcome would result in the farmer not being able to meet his subsistence income while in the second case the bad year outcome would exceed the level.

[b] Computed from tables 2, 3, and 4 by combining the data for sharecroppers and small farmers. The 103 respondents do not include 15 respondents who were not willing to answer the questions or whose answers were internally inconsistent, as judged by the interviewers. Similarly, the 222 farmers in the Indian interview studies excludes roughly 10 respondents on similar grounds.

for the Rs.50 and Rs.500 levels, which come closest to the usually higher payoff levels used in the interviews. The interview results classify more than 50% of individuals as extremely or severely risk-averse and close to 15% as neutral or negative. This is in sharp contrast to the game results for the same households. Dillon and Scandizzo give explicit data on the slight-to-neutral and negative classes of risk aversion, but not on the "extreme" classification. In table 5, lines E and F show individuals in the extreme class who opted for the highest possible certainty equivalent in their study. Interestingly, the interview results for Brazil are somewhat similar to those for India, identifying substantial proportions of individuals with extreme and negative risk aversion. Other interview-based studies also appear to find higher dispersion of risk-aversion coefficients than those identified here (O'Mara, Kennedy).

Given the clearly documented interviewer biases and high instability of interview results relative to game results, one is tempted to dismiss the interview studies as unreliable and potentially misleading. Some caution may be necessary, however, because the interview methods differ in significant ways from the game method. First, the interviews about an income stream from assets or occupations, while the game results are about one-period gambles. In the light of footnote 1, it is conceivable that the two methods measure different concepts. Second, the distribution of outcomes is skewed in the interviews but symmetric in the games.

On the other hand, one should not underestimate the problems associated with any interview method. In the third section, it was shown that at the early stages of the game sequence the respondents' replies to hypothetical questions at the Rs.50 level differed significantly from the real choices and implied much more dispersed risk-aversion distributions. Furthermore, the distributions also were more widely spread at the very low game level of one-half-rupee than at high game levels. Interview methods are inevitably faced with the problem that individuals may not be able to reveal their attitudes towards decisions they have never taken or seriously contemplated. And even if the payoffs discussed in hypothetical questions are high, there are no real payoffs or penalties associated with revealing a preference which may or may not correspond to how one would act when faced with real choices, i.e., true payoffs are even lower than those in the one-half-rupee game.

Correlation of Risk Aversion with Personal Characteristics

Empirically, virtually nothing is known about how personal characteristics of individuals are correlated with risk aversion. This section is concerned with correlations of risk aversion

with personal characteristics regardless of the causal nature of the relationship and therefore can look at personal characteristics that may be determined jointly with risk aversion. In order to use multiple regression, a number of scaling decisions have to be made to assign risk-aversion "numbers" to the discreet classes. At the simplest level, numbers zero to five are given to the choices O to F, and they are used as regressors. Other scales are based on the tradeoff Z and on partial risk aversion S. A substantial number of regressions were performed using these three variables and functional transformations thereof. These variables and transformations had little impact on the sign patterns of the coefficients, but the regressions using ln S had, on an average, the highest $\bar{R}^2$, and are therefore retained. Furthermore, the full data set was divided into subsets of different villages and for males and females separately. F-tests indicated that these sets could be combined for all games, i.e., coefficients did not differ significantly across data subsets. The regressions in table 6, however, exclude the dependent females data because their observations are not independent of those of the household heads. Signs and significant levels of coefficients were fairly

Table 6. Regression of Personal Characteristics on Partial Risk Aversion

	0.5 Rupees		5 Rupees		50 Rupees	500 Rupees
	No. 2 (1)	No. 5 (2)	No. 7 (3)	No. 9 (4)	No. 12 (5)	No. 16 (6)
Intercept	−2.975	−1.894	−0.238	−3.498	0.202	0.421
Village 1	0.734	−0.018	−0.320	1.859	0.404	−0.314
	(1.194)	(0.032)	(0.696)	(3.792)*	(1.295)	(1.804)*
Village 2	1.569	−0.526	−0.776	1.809		
	(2.663)	(0.873)	(1.766)*	(3.851)*		
Village 3	1.576	1.286	0.252	2.343	0.573	−0.165
	(2.620)*	(2.112)*	(0.567)	(4.938)*	(1.965)*	(1.010)
Village 4	0.918	−0.484	−0.304	1.378		
	(1.563)	(0.797)	(0.686)	(2.880)*		
Village 5	−0.387	−1.165	−0.918	1.254		
	(0.692)	(2.051)*	(2.222)*	(2.838)*		
Women	0.810	1.100	0.204	−0.878	−0.073	−0.027
	(1.337)	(1.1785)*	(0.456)	(1.832)*	(0.184)	(0.122)
Progressive farmer dummy	−0.245	−1.187	−1.141	0.088	−0.193	−0.320
	(0.391)	(1.869)*	(2.473)*	(0.179)	(0.424)	(1.259)
Working age adults	0.452	−0.761	0.092	1.070	0.081	0.328
(weighted share age 15–59)	(0.594)	(0.992)	(0.167)	(1.794)	(0.161)	(1.167)
Salary (Rs.1000/month)	0.232	−0.051	−0.493	−0.294	−0.141	−0.208
	(0.769)	(0.164)	(2.213)*	(1.232)	(0.645)	(1.700)*
Land rented (hectares)	−0.092	−0.233	−0.049	0.012	0.053	0.0008
	(1.232)	(3.072)*	(0.891)	(0.210)	(0.748)	(0.000)
Gambler dummy	−1.087	−0.591	0.381	−1.300	−0.125	0.210
	(0.837)	(0.447)	(0.397)	(1.268)	(0.195)	(0.583)
Age (years)	0.017	0.023	0.009	0.021	−0.016	−0.0025
	(1.202)	(1.573)	(0.848)	(1.894)	(1.648)	(0.465)
Schooling (years)	0.061	−0.027	−0.105	−0.012	−0.038	−0.037
	(0.984)	(0.424)	(2.311)*	(0.241)	(0.915)	(1.586)
Assets (in 1000 Rs.)	−0.019	−0.0055	−0.0041	−0.012	0.0032	−0.001
	(2.491)*	(0.735)	(0.744)	(2.068)*	(0.568)	(0.345)
Net transfers	−0.247	−0.502	−0.388	−0.241	−0.055	0.005
(received in 1000 Rs.)	(1.021)	(2.048)*	(2.176)*	(1.265)	(0.437)	(0.071)
Luck	−0.240	−0.269	−0.156	−0.145	−0.133	−0.043
	(1.428)	(3.015)*	(2.549)*	(2.399)*	(2.641)*	(1.672)*
$\bar{R}^2$	0.110	0.179	0.202	0.205	0.034	0.088
F	2.762	4.096	4.598	4.653	1.302	1.814
N observations	228	228	228	228	111	111

Note: Asterisks denote significance at the 10% level of probability.

robust in these experiments with functional forms, and, where that was not the case, it will be signalled in the text.[5]

For the partial risk-aversion coefficient S, the following scaling decisions are involved. The choices of an alternative indicate a range only for S. The geometric mean of the end points is assigned as the measure of S.[6] In the case of alternative F, a value of zero is given to S although it could be negative. Given the result that practically no one prefers risk at high game levels, a value of zero is not unreasonable.[7] For alternative O, the upper bound for S is equal to infinity, while its lower bound is 7.50. Because in the experiment very few individuals chose alternative O, it is reasonable to assume that their partial risk aversion should not exceed 7.5 by very much, and this value was increased by 12% to give a value of 8.4. It is easy to find fault with any of these scaling decisions, and they can be defended only by the apparent insensitivity of results to alternative scalings.

In table 6, the coefficients of the variables with ln S are given. To judge the magnitude of the effects implied, table 7 computes a predicted S for the Rs..5 and Rs.50 levels and compares it with the geometric average S in the sample (first line, underlined values). The predicted S is computed as follows: add to the average S the shift implied by the regression coefficient for a move from the average value of the independent variable to the largest value observed in the sample.[8] Table 7 also shows which choice would be implied by the new value of S.

Thirteen variables are included in the regressions, apart from the village dummies, which are included to take account of effects on risk aversion of such variables as agroclimatic differences, and others.

In the regressions, wealth is measured by gross sales value of physical assets. It would have been better to use net worth rather than gross wealth. However, the data on borrowings and lendings are scanty, but imply that at higher wealth levels borrowings were a small fraction of gross wealth. In these households, on an average, 69% of physical wealth was held in the form of land. The weakness of the relationship between physical assets and risk aversion is surprising, given the fairly strong effect of the game size. Across games the sign of the coefficient is consistently negative, but not always statistically significant. The (statistically not significant) coefficient of −0.0041 in the 5-rupee game 7 implies that a shift from average wealth to the largest wealth observed in the sample is just sufficient to bring an individual from choice C to risk neutrality. It would not be sufficient to move an individual

[5] A decision also had to be taken as to what to do with the "inefficient choices" D and D^*. Leaving out everyone who chose an inefficient alternative at least once would have drastically cut the sample. A comparison of regression where they were left out with regressions where choice D was treated as its neighboring choice B and choice D^* as choice C revealed no differences in sign patterns and coefficient sizes but reduced standard errors. The results reported thus include the inefficient choices.

[6] For alternative E at one of the endpoints, $S = 0$ and the geometric mean of both endpoints would be zero. Therefore, the arithmetic mean was chosen in this case.

[7] For logarithmic transformations, a value of zero is inadmissible. It was therefore rather arbitrarily set at 0.0007.

[8] Predicted

$$S = \exp\left(\frac{1}{n}\, \Sigma_i \log S_i\right) + \exp\,[b_j(X_{j\max} - \bar{X}_j)],$$

where n is the sample size, and X_j the jth indpendent variable, $\bar{X}_j$ is the arithmetic mean, and b_j is its estimated coefficient.

Table 7. The Largest Possible Shifts in Choices Implied by the Regression Results

Explanatory Variable	Maximum Minus Mean Value[a]	Predicted S at Rs.5 Level	Choice Implied	Predicted S at Rs.50 Level	Choice Implied
Average S[b]		0.483	*C*	0.705	*C*
Women	1	0.592	*C*	0.758	*C*
Progressive	1	0.154	*E*	0.581	*C*
Working adults (share age, 15–59)	0.5	0.506	*C*	0.734	*C*
Salary (Rs.1000)	Rs.5.069	0.040	*E*	0.345	*C*
Age	38 years	0.680	*C*	0.384	*C*
Schooling	12 years	0.137	*E*	0.447	*C*
Assets (Rs.1000)	185.277	0.226	*E*	—[c]	
Transfer income (Rs.1000)	6.224	0.043	*E*	0.501	*C*
Luck	5	0.221	*E*	0.363	*C*

[a] For dummy variables the value taken was one.
[b] Antilog of average of ln S.
[c] Coefficient has wrong sign.

who initially was indifferent between A and B to choose alternative E.

For the crucial 50-rupee game, the coefficient is usually of the unexpected sign (positive, close to zero, and not significant). Contrary to expectations, wealth has little impact on individuals' behavior at game levels that are commensurate with monthly wage rates or small agricultural investments.

Another form of wealth is human wealth and "schooling" is a proxy variable for it. Average schooling in the sample is two years, but the maximum is sixteen years, i.e., the distribution is highly skewed. At low game levels this variable had little influence on risk aversion, but at the Rs.5 level and above, it generally reduced the level of risk aversion and was often statistically significant, although not generally so in the regressions using log S. But again, the impact of schooling was not massive. In the 5-rupee game, the coefficient size of -0.0432 implies that an individual who has fourteen years of schooling rather than one would fall into the slight-to-neutral class rather than the intermediate class. At the Rs.50 level, the same difference is not sufficient to shift the individual's risk aversion by an entire class interval.

Two variables that are correlated with schooling are the amount of income received in the form of salary (i.e., from a secure job) and a dummy variable for progressive farmers. Salary employment, with some exceptions, is restricted to individuals with schooling, and totally illiterate individuals have no access to it (58% of the household head sample had no schooling). Progressive farmers are those whom the resident investigators designated as the early adopters of new techniques (five in each village). Schooling is again correlated with this variable and can be expected to contribute to it. Note that in regressions where these two variables were suppressed, schooling did become statistically significant.

"Salary employment" by itself tended to decrease risk aversion, the sign being fairly consistently negative, although it was not statistically significant at the Rs.50 level. Similarly, the progressive farmer dummy had a fairly consistent negative sign, but at the high game levels its coefficient was so small that it was not significant.

Economists would not usually expect that past experience with a random process, which is as transparent as flipping a coin, would have a strong impact on a person's next choice over alternatives defined on it. Psychologists, on the other hand, would not find this surprising, and the present experiment suggests a strong impact of prior luck. Past experience, or luck, is defined as $\sum_i X_i$, where i is the game number 1, 2, 3, 4, 5, 7, 9, and 12, and X takes a value of 1 when the person wins, -1 when he loses, and zero when he neither wins nor loses (alternative O). The coefficient is consistently negative and always statistically significant. Note also that its size tends to decline as the game level rises, i.e., its impact is weaker the higher the stakes. Nevertheless, at the Rs.5 level (after seven games), a person who had consistently won (luck = +7) would have a greater tendency to shift from playing alternative C to playing alternative E than a person who had had an equal number of gains and losses. Finally, past experience does not wear off rapidly. The answers to the 500-rupee game were collected two or more weeks after the last game had actually been played.

Whether the influencing of this variable reflects revision of personal probabilities, or learning about them, or some other effects cannot be answered by this experiment.[9] Because "luck" in this experiment is a random variable uncorrelated among individuals it has impact on individual choices but not on the risk-aversion distributions. However, farmers in a given area face highly correlated weather outcomes. That past experience should have such an impact on risk aversion suggests that farmers would be more reluctant to invest after a series of droughts (even if they had the same wealth levels as before the drought) than they normally would on account of their own average risk aversion.

Age has a positive sign in games up to the Rs.5 level but a negative sign at the Rs.50 and Rs.500 level. At the Rs.50 level it is statistically significant but not at the Rs.500 level. Is it possible that young people are more willing to engage in risky games at low stakes, whereas older people having dealt much more in risky economic games at high stakes might be more willing to take risks at high levels? But at the Rs.50 level, the quantitative impact

[9] Psychologists working experimentally in the area have found that individuals exhibit preferences for heads or tails in coin tosses. Because the winning sign of the coin was charged for each game level, such preference cannot account for the observations on the luck variable. But it is possible that the preferences for one side of the coin seen in earlier experimental work might be caused by a person having had a winning or losing streak on one side of the coin.

of even thirty-eight years of age difference is not sufficient to shift an individual's choice by an entire class interval.

The "women" dummy variable exhibits inconsistent coefficient signs. At high game levels it does not appear to affect behavior at all. Clearly, there is little support for the hypothesis that women are less willing to take risks than men, once adjustment is made for variables such as schooling. In tabular analysis it was noted that, on an average, women were slightly more risk-averse than men (means not significantly different). At best, one can explain this by the fact that, in the environment studied, women did not have equal access to education as men. Not a single woman in the sample ever attended school.

The variable "working age adults" approximates the proportion of productive individuals in a household: it varies on the unit interval, i.e., it is the weighted number of adults between the ages of fifteen and fifty-nine years divided by the weighted sum of family members.[10] The lower this ratio, the higher the proportion of individuals whom the working age adults have to support. One would thus expect the variable to have a negative sign by saying that those with few dependents can afford to take more risk. This hypothesis is not supported by the data. The coefficient shifts in sign and is hardly ever significant. At higher game levels it is consistently positive, i.e., of unexpected sign.

A portion of the new literature on tenancy assumes that share tenancy is used to spread the riskiness of farming (Bardhan and Srinivasan). The reasoning is not based on differential risk aversion between landlords and tenants, but it would be strengthened considerably if tenants were generally more risk-averse than landlords. The "land rented" variable measures the net area leased by a household regardless of the form of contract. It is negative for landlords and positive for tenants. At low game levels there was some indication that tenants were less risk-averse than landlords, not vice-versa. At high game levels there appeared to be no difference.

"Net transfers received" measures the net amount of income transfers received from relatives and other sources between 1 July 1975 and 30 June 1976. It was negative for those who sent transfers. It usually had a negative sign, which is consistent with the hypothesis that the possibility to rely on income transfers reduces risk aversion because it insures against adversity. It is not a good measure of "insurance" via transfer mechanisms because it measures what has actually been received rather than what can potentially be received, yet it is the best that can be done at this stage.

The individuals who liked to gamble (by buying lottery tickets or by playing cards, with and without money) were identified. Less than 5% of individuals fell in this category, and the variable leads to contradictory results.

Table 5 shows that coefficient sizes were generally smaller at the Rs.50 level than at the Rs.5 level. This is not surprising because the distribution of risk-aversion coefficients is more concentrated at the Rs.50 level than at the Rs.5 level.

Gambling Results and Farming Decisions

As measured by the gambling experiment, the main conclusions of this study are as follows: (*a*) At very low payoff levels, risk aversion is fairly widely distributed from intermediate levels to risk neutrality or preference. (*b*) At payoff levels in the neighborhood of monthly labor incomes or small agricultural investments, risk aversion is highly concentrated at the intermediate and moderate levels, and risk neutrality virtually disappears. (*c*) At these high payoff levels, wealth does not appear to influence risk aversion significantly, although at low game levels such an effect appears to exist.

If these results can be extrapolated to farming decisions, they suggest that differences in investment behavior observed among farmers facing similar technologies and risks cannot be explained primarily by differences in their attitudes but would have to be explained by differences in their constraint sets, such as access to credit, marketing, extension, etc. It is not the innate or acquired tastes that hold the poor back but external constraints. Policy in support of poor farmers and landless laborers will have to be geared toward removing these constraints rather than being risk-specific.

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[10] In computing the ratio, adult males (above 15 years of age) were given a weight of 1; adult females, 0.8; and children, 0.5.

References

Bardhan, P. K., and T. N. Srinivasan. "Crop-Sharing Tenancy in Agriculture: A Theoretical and Empirical Analysis." *Amer. Econ. Rev.* 61(1971):48–64.

Binswanger, Hans P. "Attitudes towards Risk, Experimental Measurement in Rural India." New Haven, Conn.: Economic Growth Center Disc. Pap. No. 285, 1978a.

———. "Risk Attitudes of Rural Households in Semi-Arid Tropical India." *Econ. and Polit. Weekly* 12(1978b):A49–A62.

———. "Attitudes towards Risk: Implications for Economic and Psychological Theories of Behavior under Risk of an Experiment in Rural India." New Haven, Conn.: Economic Growth Center Disc. Pap. No. 286, 1978c.

Binswanger, Hans P., and N. S. Jodha. "ICRISAT Village Level Studies: Manual of Instructions for Economic Investigators." Mimeographed. Hyderabad: ICRISAT, June 1976.

Dillon, John L., and Pasquale L. Scandizzo. "Risk Attitudes of Subsistence Farmers in Northeast Brazil: A Sampling Approach." *Amer. J. Agr. Econ.* 60 (1978):425–35.

Jodha, N. S., M. Asokan, and James G. Ryan. "Village Study Methodology and Resource Endowments of the Selected Villages in ICRISAT's Village Level Studies." Hyderabad: ICRISAT, Economics Program Occas. Pap. No. 16, Nov. 1977.

Kennedy, John O. S. "Indifference Curves for Expected Income and Focus-Loss Income: Measurement and Applications in Agriculture." *Uncertainty and Agricultural Development*, ed. James A. Roumasset, Jean-Mark Boussard, and Inderjit Singh, pp. 161–74. Laguna, Philippines: Agricultural Development Council and Southeast Asian Regional Center for Graduate Study and Research in Agriculture, 1978.

Lipton, Michael. "Agricultural Risk, Rural Credit and Inefficiency of Inequality." *Uncertainty and Agricultural Development*, ed. James A. Roumasset, Jean-Mark Boussard, and Inderjit Singh, pp. 341–79. Laguna, Philippines: Agricultural Development Council and Southeast Asian Regional Center for Graduate Study and Research in Agriculture, 1978.

Luce, R. D., and P. Suppes. "Preference Utility and Subjective Probability." *Handbook of Mathematical Psychology*, ed. R. D. Luce et al. New York: John Wiley & Sons, 1965.

Masson, Robert T. "The Creation of Risk Aversion by Imperfect Capital Markets." *Amer. Econ. Rev.* 62(1972):77–86.

Menezes, C. F., and D. L. Hanson. "On the Theory of Risk Aversion." *Int. Econ. Rev.* 62(1972):77–86.

Officer, R. R., and A. H. Halter. "Utility Analysis in a Practical Setting." *Amer. J. Agr. Econ.* 50 (1968):257–77.

O'Mara, G. T. "A Decision Theoretic Framework of the Microeconomics of Technique Diffusion in a Developing Country." Ph.D. thesis, Stanford University, 1971.

Roumasset, James A. "Introduction and State of the Arts." *Uncertainty and Agricultural Development*, ed. James A. Roumasset, Jean-Mark Boussard, and Inderjit Singh, pp. 3–22. Laguna, Philippines: Agricultural Development Council and Southeast Asian Regional Center for Graduate Study and Research in Agriculture, 1978a.

———. "Risk Aversion, Indirect Utility Functions and Market Failure." *Uncertainty and Agricultural Development*, ed. James A. Roumasset, Jean-Mark Boussard, and Inderjit Singh, pp. 93-114. Laguna, Philippines: Agricultural Development Council and Southeast Asian Regional Center for Graduate Study and Research in Agriculture, 1978b.

Roumasset, James A., Jean-Mark Boussard, and Inderjit Singh, eds. *Uncertainty and Agricultural Development*. Laguna, Philippines: Agricultural Development Council and Southeast Asian Regional Center for Graduate Study and Research in Agriculture, 1978.

Samuelson, Paul A. "St. Petersburg Paradoxes: Defanged, Dissected and Historically Described." *J. Econ. Lit.* 15(1977):24–55.

Zeckhauser, R., and E. Keeler. "Another Type of Risk Aversion." *Econometrica* 38(1970):661–65.

U.S. Agricultural Policy and Gasohol: A Policy Simulation

Ronald L. Meekhof, Wallace E. Tyner, and Forrest D. Holland

This research uses a stochastic simulation model to evaluate the implications of alternative gasohol programs for a large segment of the food and agricultural sector—corn and soybean producers, consumers, and taxpayers. The impacts on corn and soybean prices, production, acreage planted, carryover stocks, exports, and commodity program expenditures are presented. The research findings indicate that alcohol production levels below 2.0 billion gallons do not result in serious dislocations in the agricultural sector. As the level of alcohol production increases and more grain is required, corn prices rise significantly, stocks fall to extremely low levels, exports decline, and government expenditures increase greatly.

Key words: agricultural policy, alcohol, energy, gasohol, simulation.

Federal policy toward oil prior to 1973 was a patchwork of restrictive measures justified on the grounds that national security required a strong oil industry. The energy policies of the United States during this period have been characterized as "surplus policies" (Mitchell). An import quota restricted domestic production in order to support the price of domestic crude. These policies were operable because there was a worldwide surplus of oil. Since the Arab oil embargo of 1973, the thrust of the U.S. energy policy has been to "manage the shortage" and stimulate supply with an intricate system of price controls for crude oil and refined products together with programs for allocations and entitlement payments.

Agricultural policy has undergone a similar transition. The underlying supply and demand conditions have not, however, dictated a stringent shortage management policy approach. Reliance on price support and supply control programs to reduce chronic over-production have given way to increased reliance on managed grain reserve programs and measures to modify the impacts of competitive and unstable markets. With the impending shortage of liquid fuels, a new set of economic factors are invoked that may warrant further change in agricultural policy.

The utilization of grain for the production of gasohol—a blend of 10% alcohol produced from grain and 90% gasoline—has gained substantial interest among those concerned with agricultural and energy policy. Gasohol production is perceived as a means of utilizing agricultural land periodically withdrawn from production to increase domestic energy supplies.

Previous research on this issue concludes that gasohol production is not currently economically viable, given current relative factor and product prices and alcohol production technology (Tyner and Bottum). With alcohol distilled from grain costing considerably more than the current wholesale price of gasoline, a subsidy would be required to make alcohol competitive on a cost basis with gasoline. Alcohol is, however, competitive with synthetic fuels derived from coal and oil shale. The wholesale cost of all these fuels will be $1.20 per gallon or higher. Yet, within the current context of rapidly rising energy prices, periodic grain surplus, and acreage set-asides, the economic implications of policy alternatives that potentially could improve resource use in both the agricultural and energy production sectors need to be evaluated.

As might be expected for an issue with important implications for both agricultural and energy policy, several gasohol program alternatives have emerged in the legislative pro-

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cess. The proposed gasohol programs generally provide (*a*) a subsidy for gasohol production, (*b*) measures to enhance the level of grain production, and (*c*) measures to assure a minimum supply of grain to distillers. Without reference to specific legislation, this paper examines an alternative agricultural program under the assumption that demand exists for grains used in gasohol production.

The analysis presented here compares a modified agricultural program designed to meet various levels of gasohol production with an extension of those programs currently in effect.[1] Under the modified program, the income and acreage set-aside programs are eliminated. Loan rates are increased to levels that would provide producers with about an equivalent production incentive and level of income protection as that provided by current commodity programs. Increased loan rates also are utilized as a means to increase inventories of the Commodity Credit Corporation, which assumes the additional marketing role of providing a minimum amount of grain to alcohol distillers. Four different levels of alcohol production are evaluated with respect to their impacts on prices, production, exports, carryover stocks, and government expenditures for corn and soybeans.[2]

Model Description

A stochastic simulation model was used to evaluate and compare the implications of the gasohol and extension of current commodity program alternatives on economic variables characterizing U.S. corn and soybean markets. *FEEDSIM*, a model of the U.S. corn and soybean markets, is comprised of annual production, demand, and government program components, and incorporates interaction in supply and demand for both commodities. Since *FEEDSIM* is documented in detail elsewhere (Holland and Meekhof), only those modifications that were necessary to address the gasohol program alternative are discussed here. Those modifications include incorporating (*a*) the commitment by the CCC to supply grain to alcohol distillers, (*b*) the subsidy needed to make alcohol production competitive, and (*c*) the impacts on soybean demand resulting from increased supplies of distillers dried grain.

The gasohol program analyzed here requires a corn supply commitment equivalent to that needed to produce 1.0, 2.0, 3.0, or 4.0 billion gallons of alcohol—385, 769, 1154, and 1538 million bushels per year of corn, respectively. The alternative levels of supply commitment are purchased and sold by the CCC. This modification is incorporated in the stocks component of the model by specifying that the CCC make available that amount of grain from either inventories accumulated through nonrecourse loan defaults or purchases from the market, which equal the difference between the levels of supply commitment and quantity defaulted. The CCC is charged the loan rate for grain withdrawn from inventories and the market price for grain purchased from the market.

The per bushel corn price used to calculate CCC revenues is that required to make gasohol competitive with gasoline—\$.75 in 1979.[3] This 1979 price is increased 10% annually in following years to reflect rising gasoline prices. The subsidy for gasohol production is equal to the difference between the average price the CCC is charged for the grain supply commitment and price for grain that makes gasohol production competitive.

The process of grain to alcohol conversion also results in the production of distillers dried grain—a protein source that substitutes for soybean meal at a rate of 2 to 1. Each bushel of grain used in gasohol production reduces domestic soybean demand by .19 bushels.[4]

[1] The original analysis included comparison of two alternative gasohol programs. The two gasohol program alternatives differ primarily in the manner in which producers are encouraged to increase production above export, domestic demand, and reserve needs to meet gasohol supply commitments. Complete results of both program alternatives are available from the authors in a paper entitled "U.S. Agricultural Policy and Gasohol: Simulation of Some Policy Alternatives."

[2] Two important issues are not covered in this analysis. First, increased row crop production would increase soil erosion. The associated loss in environmental quality has not been considered explicitly in this analysis. Clearly, however, any policy decisions would include this important factor. Second, net energy analysis is not included here because of space limitations. The general consensus is, however, that with current technology for new plants, alcohol production is a net producer of premium fuels even with increased fertilizer use.

[3] Seventy-five cents was the corn price required to make alcohol cost competitive with gasoline in April 1979. If petroleum prices rise faster than our assumed 10% per year, the break-even price would be higher and CCC subsidies lower than the results here indicate.

[4] Modifications incorporated in the model specify full utilization of the distillers grain as a protein substitute for soybean meal. While this is not likely, the modification was done in this manner to illustrate the most severe case. It is more likely that some of the distillers grain would be fed wet as corn substitute. To the extent that the corn substitution occurred, soybean demand would be diminished less than indicated in these results. The results shown here should be interpreted with this factor under consideration.

Current utilization levels indicate that the substitution possibility of distillers dried grain for soybean meal would cease to exist for alcohol production levels greater than 3.0 billion gallons because that amount of distillers grain would substitute for all currently fed soybean meal.

Program Alternatives

The analysis compares the gasohol program alternative and an extension of current commodity programs for the period 1979/80 through 1984/85. Assumptions are made with respect to the level of commodity program parameters for each alternative for individual years in that period.

The current program alternative (*CURRENT*) incorporates announced target prices, loan rates, set-aside levels, and reserve program parameters for 1978/79–79/80. Target prices in the remainder of the period are adjusted on the basis of the formula contained in the Food and Agriculture Act of 1977 and projected input costs. Loan rates, and corresponding farmer-held reserve parameters, are escalated on the basis of the trend in corn prices received by producers from 1960–76. Set-aside levels are calculated internally by the model. The specific values for the *CURRENT* program parameters are shown in table 1.

Other limitations of the model include the exclusion of acreage responses from other feed grains and other sources of adjustment that may, in the long run, ameliorate the increased demand levels, and stockholding by alcohol distillers to buffer severe supply and demand conditions.

Announced program parameters for 1978/79–79/80 also are specified for the gasohol program alternative, *GAS-I*, with the exception of the 1979/80 loan rate being raised to $2.10. The loan rate for 1980/81 is set at $2.20 and adjusted in subsequent periods by the target-price adjustment formula specified in the 1977 Act and projected input costs. Farmer-held reserve (*FHR*) program parameters reflect these adjusted loan rates. Both target prices and acreage set-aside programs are eliminated for the 1980/81–84/85 period. One-half of the supply commitment levels specified above would be utilized in 1980/81 with full supply commitment levels being in effect in remaining years. Specific values for program parameters under *GAS-I* are shown in table 1.

Empirical Results

The following discussion emphasizes empirical results for supply commitment levels of 769 and 1538 million bushels for the *GAS-I* alternative (corresponding to 2 and 4 billion gallons of alcohol). These levels are representative of, and are referred to in the text, as low and high levels of alcohol production.[5]

Acreage Planted and Production

In the later years of the period considered, corn acreage planted for *GAS-I* is substantially

[5] Our current gasoline consumption is about 110 billion gallons per year so these levels are about 2% and 4% of total gasoline consumption. While these are small amounts relative to our total gasoline consumption, they are quite large relative to the magnitude of recent supply disruptions.

Table 1. Program Parameters for *CURRENT* and *GAS-I*

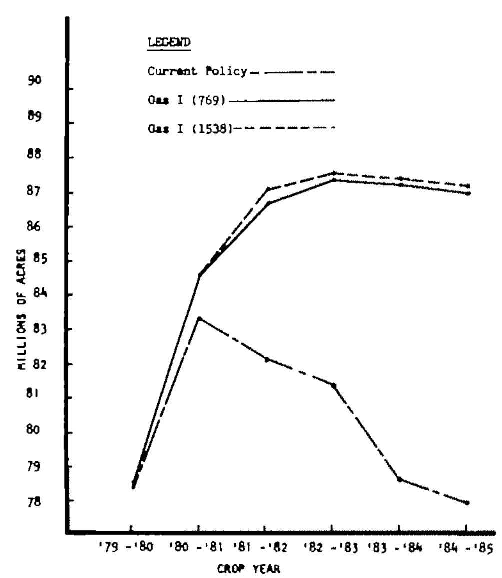
	1978/79	1979/80	1980/81	1981/82	1982/83	1983/84	1984/85
CURRENT							
Target price	2.10	2.20	2.26	2.41	2.47	2.53	2.59
Loan rate	2.00	2.00	2.07	2.14	2.22	2.29	2.37
FHR release price	2.50	2.50	2.59	2.67	2.77	2.86	2.96
FHR call price	2.80	2.80	2.90	3.00	3.11	3.21	3.32
CCC release price	3.00	3.00	3.10	3.21	3.33	3.43	3.55
GAS-I							
Target price	2.10	2.20	0.0	0.0	0.0	0.0	0.0
Loan rate	2.00	2.10	2.20	2.35	2.41	2.47	2.53
FHR release price	2.50	2.62	2.75	2.94	3.01	3.09	3.16
FHR call price	2.80	2.94	3.08	3.29	3.37	3.46	3.54
CCC release price	3.00	[a]					

[a] Under the *GAS-I* program, the CCC only releases stocks to meet gasohol supply commitments, thus altering currently employed provisions of releasing stocks at 150% of the loan rate.

higher than those indicated under the *CURRENT* alternative. The difference of 7 to 10 million acres is caused largely by the acreage response to higher corn prices relative to soybeans and the elimination of acreage set-asides. With corn yields averaging about 3.5 bushels per acre less under the *GAS-I* levels of production, the difference in production is less than that indicated by acreage differences. The average difference in production between *GAS-I* and the *CURRENT* alternative is 250 million bushels for both the low and high cases.

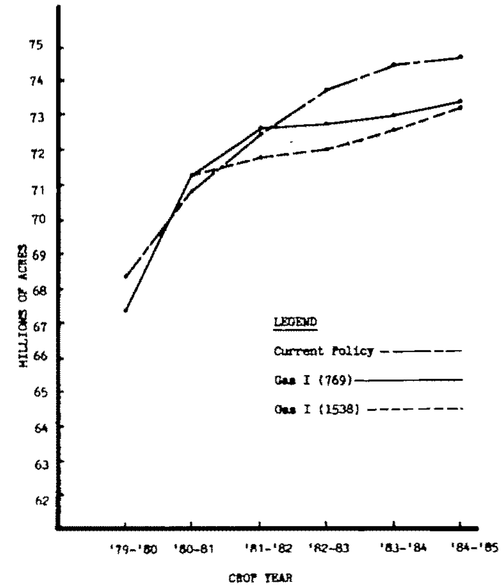
Figure 1 indicates no substantial differences between corn acreage planted under *GAS-I* for high or low levels of alcohol production. Corn acreage planted increases substantially with introduction of the gasohol programs and holds steady between 86 and 87 million acres in later years. Corn acreage for *CURRENT* averages 80 million acres for 1980/81–84/85 due to acreage set-asides.

Soybean acres show steady increases through most of the period of analysis under both the *CURRENT* and *GAS-I* alternatives (figure 2). Low levels of alcohol production reduce soybean acreage by, at most, 1.5 million acres, while at high levels of alcohol production the reduction is no larger than 1.9 million acres. The impacts on soybean acreage are explained largely by factors on both the supply and demand sides. Soybean demand is



Legend: —·— *CURRENT* Program;
····· *GAS-I* (Corn 769) Program;
——— *GAS-I* (Corn 1538) Program

Figure 1. Acres planted of corn



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····· *GASOHOL-I* (Corn 769) Program;
——— *GASOHOL-I* (Corn 1538) Program

Figure 2. Acres planted of soybeans

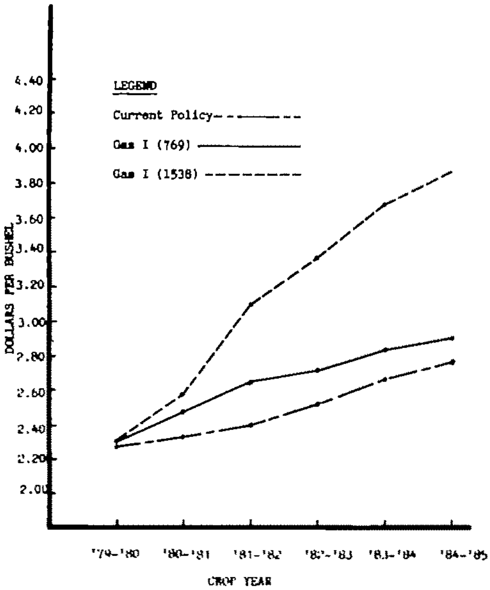
reduced because of the substitution of distillers dried grain for soybean meal. On the supply side, the relatively higher corn prices under the *GAS-I* alternative induce planting of more corn acreage and less soybean acreage.

Total corn and soybean acreage increase under the *GAS-I* alternative. Total acreage for both commodities averaged 153.7 million acres for *CURRENT* and 159.2 for the 2.0 billion gallon level under *GAS-I*. Total acreage did not vary substantially between high and low alcohol production levels for the *GAS-I* alternative. Over the last three years of the period of analysis, acreage planted for both commodities stabilized at levels about 8 million acres greater than *CURRENT* under *GAS-I*.

Prices

Figure 3 shows that corn prices under *GAS-I* are higher than with *CURRENT*, which average $2.53 per bushel over 1980/81–84/85. Corn prices for high levels of gasohol production are substantially higher, while corn prices at the 2 billion gallon alcohol production level average $.17 higher for *GAS-I* over the same period. The difference in prices between *CURRENT* and the 1.0 billion gallon level were negligible.

The stability of corn prices, as measured by the coefficient of variation, under low levels of alcohol production for *GAS-I* does not sig-



Legend: –·– *CURRENT* Program;
····· *GASOHOL-I* (Corn 769) Program;
--- *GASOHOL-I* (Corn 1538) Program

Figure 3. Corn prices

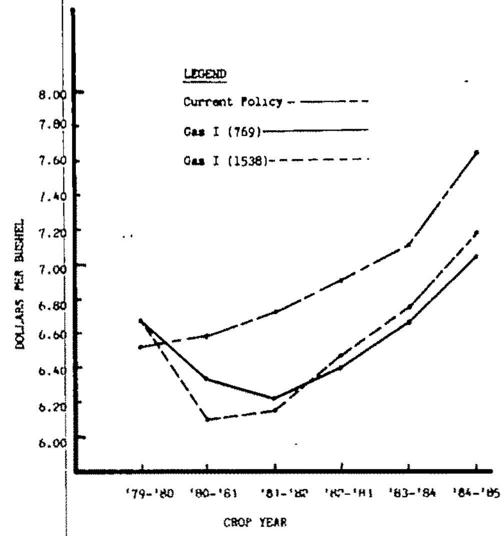
nificantly differ from *CURRENT* levels. However, the coefficient of variation for high levels of production under *GAS-I* increased by 66%. Soybean prices were not destabilized under the *GAS-I* program.

Soybean prices with the *CURRENT* program alternative average $7.00 per bushel from 1980/81 to 1984/85. High and low alcohol production levels under *GAS-I* resulted in average soybean prices of $6.52. The difference in soybean prices between *GAS-I* and *CURRENT*, which are shown in figure 4, was lower at the end of the period of analysis.

Exports

Figure 5 indicates that corn exports under low levels of gasohol production do not differ substantially from those with the *CURRENT* alternative, while for high levels of gasohol production, corn exports decrease by 200–300 million bushels in the middle of the period of analysis. The rebound in corn exports in the later years reflects the relative increase in soybean prices that occurred.

Evaluated at season average prices, the value of corn exports under *CURRENT* average $5.2 billion annually for 1980/81–84/85. At high levels of alcohol production, annual corn export values approach $6.0 billion. For high levels, however, instability in corn export



Legend: –·– *CURRENT* Program;
····· *GASOHOL-I* (Corn 769) Program;
--- *GASOHOL-I* (Corn 1538) Program

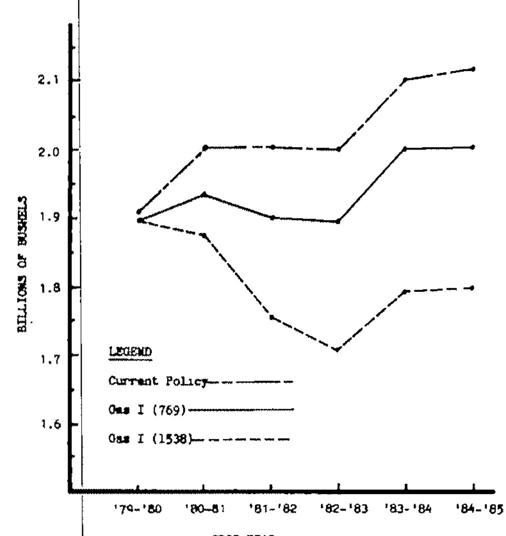
Figure 4. Soybean prices

quantities increases by 30%–40% under *GAS-I* for later years in the analysis.

The decrease in domestic soybean demand due to the substitution of distillers dried grain is partially balanced by increased exports as is shown in figure 6.

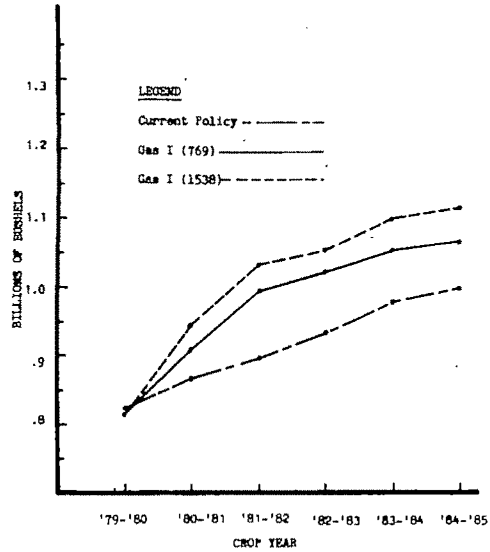
Corn Carryout Stocks

As is shown in figure 7, corn carryout stocks are lower with *GAS-I* than those under *CUR-*



Legend: –·– *CURRENT* Program;
····· *GASOHOL-I* (Corn 769) Program;
--- *GASOHOL-I* (Corn 1538) Program

Figure 5. Corn exports

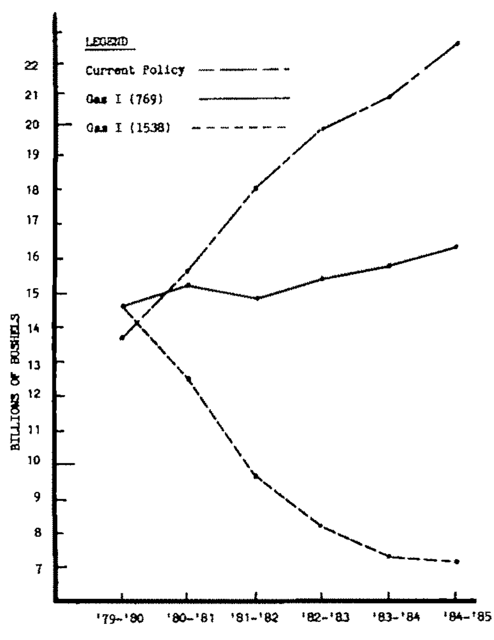


Legend: - · - *CURRENT* Program;
· · · · · *GASOHOL-I* (Corn 769) Program;
– – – *GASOHOL-I* (Corn 1538) Program

Figure 6. Soybean exports

RENT alternative. The results also indicate that the reduction in stocks varies directly with the alcohol production level. At low levels of alcohol production the level of private stocks—the primary cushion for supply and demand shocks—are not significantly reduced. For the period 1980/81–84/85, private stock levels hold steady at about 1.1 billion bushels for *CURRENT* and *GAS-I* alternatives at the 2.0 billion gallon alcohol production level. For production levels of 3.0 and 4.0 billion gallons, private carryout stocks average about 900 million bushels and also trend downward to about 700 million bushels in 1984/85. At the 4.0 billion gallon level, average annual farmer-held reserve stocks are reduced to about 200 million bushels for *GAS-I*.

For alcohol production levels greater than 2.0 billion gallons, CCC carryout stocks are negligible. The frequency of CCC market purchases averaged 85% for *GAS-I* at the 4.0 billion gallon level. The trend in the frequency of CCC intervention in the market to meet alcohol production needs increased through time at high production levels.

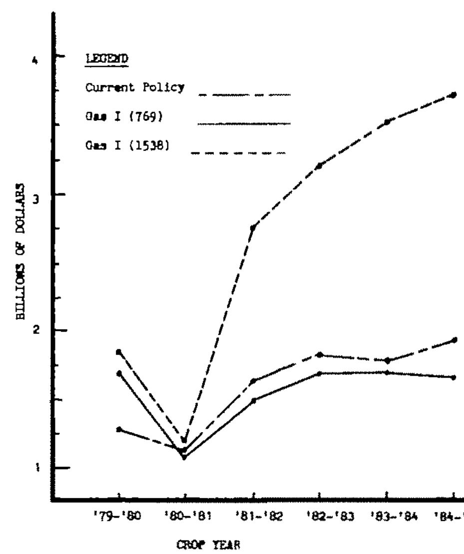


Legend: - · - *CURRENT* Program;
· · · · · *GASOHOL-I* (Corn 769) Program;
– – – *GASOHOL-I* (Corn 1538) Program

Figure 7. Carryout stocks of corn

Government Expenditures

Government expenditures for CCC operations, income deficiency payments, acreage diversion payments, and FHR storage payment with the *GAS-I* alternative were generally greater than those for *CURRENT* at high alcohol production levels. For the 1.0 and 2.0 billion gallon alcohol production level, government expenditures were about the same for *GAS-I* and *CURRENT*. As is shown on figure 8, the level of government expenditure is sub-



Legend: - · - *CURRENT* Program;
· · · · · *GASOHOL-I* (Corn 769) Program;
– – – *GASOHOL-I* (Corn 1538) Program

Figure 8. Government expenditures for corn programs

stantially higher for high levels of alcohol production than for *CURRENT*.

Summary and Conclusions

The analysis provides a comparison between a policy alternative for various levels of alcohol production and an extension of current commodity programs. In general, it can be concluded that high levels of alcohol production result in outcomes that are probably not acceptable in the current food and agricultural policy context. From 1980/81 to 1984/85, season average corn prices increase from $2.53 under the *CURRENT* program to $3.32 for the 4.0 billion gallon alcohol production level. The annual instability in corn prices nearly doubles in some years at this level. Both results conflict with the interests of domestic and foreign consumers of U.S. corn and also with U.S. market stabilization objectives.

Private corn carryout stocks, the primary means to moderate supply and demand shocks are reduced by approximately 30% with the 4.0 billion gallon alcohol production level. Total stocks which include private and CCC stocks, are reduced by approximately 55%. While the implications for the ability to moderate either drastic supply reduction or demand increases is obvious, stock reductions to these levels may also impose constraints on meeting food security objectives.

At the 4.0 billion gallon alcohol production level, corn exports decrease by an average of 273 million bushels annually in 1980/81–84/85. Soybean exports increase by an average of 115 million bushels for this period. While corn export earnings increase by $.7 billion and soybean export earnings by $.3 billion at the 4.0 billion gallon level, the instability in corn export earnings increases by 35% in the later years of the period evaluated.

At the 4.0 billion gallon alcohol production level, government expenditures increase by an annual average of $1.3 billion for 1980/81–84/85—almost twice the average government expenditures for the *CURRENT* program for the same period.

At the 1.0 or 2.0 billion gallon alcohol production level, the results were quite different. Table 2 displays average values for 1980/81–84/85 for *CURRENT* and 1.0 and 2.0 billion gallon levels for *GAS-I*. Comparison of season average corn prices indicates little or no impact at 1.0 billion gallons of alcohol production. For 2.0 billion gallons, however, a $.17 per bushel increase is observed for *GAS-I*. The level of corn price instability is not affected. Soybean prices decrease significantly under these levels for *GAS-I*. Over the five-year period, planted acreage of corn increases by about 6 million acres under *GAS-I*. The difference in crop yields for higher acreage levels influence production levels.

Exports of corn do not differ significantly from *CURRENT* levels, while some strengthening is observed in soybean exports under the *GAS-I* alternative. The stability of corn exports is not affected at these levels. Total corn carryout stocks, while reduced from *CURRENT* levels, remain at sufficient levels to meet unexpected supply reductions or demand increases.

The value of corn production plus deficiency payments for corn producers in-

Table 2. Average Results at Low Levels of Alcohol Production—1980/81–84/85

Item	Units	*CURRENT* Program	*GAS-I* 1 Billion Gallon	*GAS-I* 2 Billion Gallon
Corn prices	$/Bu.	2.53	2.56	2.70
Soybean prices	$/Bu.	7.00	6.66	6.52
Corn acreage	Mil. Acres	80.4	86.5	86.7
Soybean acreage	Mil. Acres	73.3	73.4	72.6
Corn production	Mil. Bu.	7250	7569	7588
Soybean production	Mil. Bu.	2188	2192	2170
Corn exports	Mil. Bu.	2056	2115	1957
Soybean exports	Mil. Bu.	932	975	1005
Corn carryout	Mil. Bu.	1960	2146	1554
Value of corn production and deficiency payments	Bil. $	18.6	19.3	20.4
Value of soybean production	Mil. $	15.0	14.4	13.9
Government expenditures	Mil. $	1626	1635	1586

crease by $1.8 billion for *GAS-I* at the 2.0 billion gallon level. At the 1.0 billion gallon level the increase is slight. The increase in income to corn producers is balanced, however, by small decreases in the income of soybean producers. Government expenditures are not significantly altered from the *CURRENT* level of $1.6 billion under *GAS-I*. The oil import savings, at first quarter 1979 prices, would be approximately $1.0 billion annually at the 2.0 billion gallon alcohol production level.

It appears that the increased supply of distillers dried grain does not cause a significant drop in soybean prices. As corn prices rise, more corn and fewer soybean acres are planted. The distillers grain, produced as a by-product of the corn conversion to alcohol, contains less protein than the soybeans that could have been grown on the same acreage. An acre of corn produces less protein than an acre of soybeans. As more corn comes into production, displacing soybeans, the supply of protein is diminished, thereby tending to raise protein prices. At the higher levels of alcohol production, the increase in corn acreage in part displaces soybean acreage. The consequent reduction in soybean acreage causes soybean prices to rise at high alcohol production levels.

In summary, differences between the *GAS-I* option and the current program generally are small at the 1.0 and 2.0 billion gallon alcohol production level. This is an important conclusion. It means that up to 2.0 billion gallons of alcohol, which amounts to 2.0% of current gasoline consumption, could be produced from agriculture economically without causing serious adverse impacts in the agricultural sector or elsewhere.

The difference between the results at low and high levels of alcohol production also is quite important. These results indicate that low levels of alcohol production can be achieved for a low resource cost. If we go beyond the 2.0 billion gallon per year output level, however, the resource cost for additional alcohol rises significantly.

Energy and Agricultural Policy

We conclude by relating our results to the analogy between energy and agricultural policy. In recent years, energy policy has moved from surplus to shortage management. Radical changes in energy policy were required to make this policy transition. In a somewhat analogous sense, agricultural policy will require rethinking if our nation decides to produce energy as well as food and feed from agriculture. The inclusion of energy from agriculture as a policy objective within the current policy set—market stability, food security, market development, income protection to producers—would necessitate a rethinking of priorities attached to the expanded set of objectives and the implications of alternative courses of action. The differences in corn and soybean price levels and stability, exports, redistribution of income within the food and agriculture sector, government expenditures, and balance of payments are factors to be considered. In this paper we have tried to indicate some of the options and their impacts on agriculture and energy.

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References

Holland, Forrest D., and Meekhof, Ronald L. *FEEDSIM: Description and Computer Program Documentation.* Purdue University Agr. Exp. Sta. Bull. No. 221, March 1979.

Mitchell, E. J. *U.S. Energy Policy, A Primer.* Washington, D.C.: American Enterprise Institute, 1974.

Tyner, Wallace E., and Bottum, J. Carroll. *Agricultural Energy Production: Economic and Policy Issues.* Purdue University Agr. Exp. Sta. Bull. No. 240, 1979.

Economics of Electrical Energy from Crop Residue Combustion with High Sulfur Coal

F. J. Hitzhusen and M. Abdallah

The economic feasibility of utilizing corn stover as a coal supplement in small to medium-sized, coal-burning steam-electric plants appears promising, particularly when the low sulfur emission value of corn stover is considered. Two case steam-electric power plants located in Ames, Iowa, and Peru, Indiana, are analyzed utilizing three harvest and collection systems and alternative values for several key technical and economic parameters. These results combined with data from a sample of steam-electric plants in the north central United States are used to assess the potential for this renewable low sulfur energy source.

Key words: corn stover, low sulfur fuel, steam-electric combustion.

The main purpose of this research is to evaluate the economic feasibility of utilizing corn stover as a coal supplement in the large number of small, coal-burning, steam-electric power plants in the north central United States. Corn stover is the crop residue remaining after the grain has been harvested. This is consistent with the worldwide search for renewable sources of energy accentuated by the rising price of nonrenewable energy sources (gas, oil, and coal) and their anticipated declining availability. When burned with high sulfur coal, corn stover is a renewable energy source and sulfur emission control material and may result in net liquid fuel savings.

Corn Stover Combustion

The energy content of crops and crop residues results from solar energy captured by plants in the photosynthesis process. Part of that energy is digestible and used as food. The major indigestible part of the plant energy is contained in agricultural crop residues and is a major subset of total biomass. Among crop residues, corn stover has the highest Btu value per unit of weight because of its relative efficiency in utilizing atmospheric carbon dioxide (CO_2) (Roller). The estimated Btu value of corn stover dry matter ranges between 6,500 British thermal units (Btu) per pound (Buchele) to 8,000 Btu per pound (Benson, Starr). The average heat value for coal is 12,200 Btu per pound. For corn stover to be economically feasible as a coal supplement, it must be cost competitive. The cost of producing a certain amount of energy (one million Btu is the conventional unit) from corn stover should be less than or equal to the cost of producing an equivalent amount of energy-using coal. The major task of this research is the determination of the cost of a unit of heat generated using corn stover for a variety of situations and assumptions.

Corn stover contains 0.017% sulfur (0.053 lbs. S_2O/MBtu) and, when burned with high sulfur coal, it functions as an emission control material potentially to meet the air pollution standards of the Environmental Protection Agency (EPA). The EPA air quality standards differ from one state to another but, generally speaking, coal of more than 1% sulfur (1.639 lbs. S_2O/MBtu, on the average) is considered "low quality coal" (Dugan). Further, 62% of the higher sulfur coal reserves in the United States are found east of the Mississippi, where 90% of the coal-fired power generation occurs. To meet the EPA sulfur emission standards, it is necessary for coal-burning power plants east of the Mississippi to import western coal, or use stack scrubbers, fluidized beds, or some other technology which may be more expen-

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sive than supplemental corn stover combustion.

In the north central United States, corn has the highest residue production of all crops grown (Stanford Research Institute). Moreover, this region is a net importer of energy and most of its coal reserve is high sulfur coal that does not meet EPA emission standards when burned alone or without treatment. For example, more than 50% of the coal in the state of Ohio, which has a considerable share of the coal production in this region has over 4% sulfur content.

Corn stover is also a soil erosion control material. It provides soil nutrients, and it also can be used for livestock feed and bedding. In determining the feasibility of corn stover as a coal supplement, the benefit of reducing the sulfur emissions externality resulting from burning high sulfur coal and the external and private costs (soil and nutrient loss) associated with the removal of stover from the soil should be considered. Other costs include the real and opportunity cost of harvest, storage, and transport of the stover. This is in contrast to limited previous research on the feasibility of stover as a fuel. Buchele and Starr analyzed stover as a fuel but did not account for some of the externalities and used engineering-type cost estimates for harvest and transport rather than opportunity costs.

Two case studies of coal-burning, steam-electric power plants chosen from the population of power plants in the north central states are used for the analysis of this problem. The Peru, Indiana, power plant is chosen to represent the numerous small plants (50 tons of stover/day) which may have limited potential for resource recovery from solid waste or garbage (Hitzhusen, Shenk, Rivet). The Ames, Iowa, power plant, converted in 1975 to use solid waste, represents slightly larger power plants (150 tons of stover/day); its operators have experience in the combustion of solid waste with coal.[1] The selection of these two power plants also represents the two most common types of boilers: the pulverized coal boiler and the stoker boiler. The Ames, Iowa, power plant has both types of boilers and Peru, Indiana, has the pulverized coal type of boiler, which is the most common in the region.

[1] In the north central states, 43% of the coal-burning, steam-electric plants have potential corn stover combustion capacity of 100 tons per day or less. Approximately two-thirds of the plants have less than 250 tons per day of stover combustion capacity. Approximately 9% of the plants have over 2,000 tons per day of corn stover combustion capacity. A stover combustion capacity of 150 tons/day with coal in a pulverized coal boiler represents a combustion capacity of approximately 400 tons/day of coal alone.

Objectives

The general objective of this study is to assess the economic feasibility of using corn stover as a fuel supplement for coal in steam-electric power plants in the north central United States.

The specific objectives are: (*a*) to determine the economic feasibility of harvesting, storing, transporting, and firing corn stover as a fuel supplement in two steam-electric plants; (*b*) to perform sensitivity analysis on the major variables such as coal prices, costs of collecting and firing stover, stover Btu content, changes in technology and the level of throughput; and (*c*) to extend the results of the case studies and sensitivity analysis to the north central states using a sample of power plants.

General Methodology

Because of the lack of a market price for corn stover, break-even point analysis is found to be the most appropriate methodology to determine the feasibility of corn stover as a fuel supplement for coal. The market for corn stover is conceptualized as having a supply (farm sector), a demand (power plant sector), and a transportation sector to link supply and demand. The quantitative relationships that determine the break-even points of each of the three sectors are formulated. The interaction between the three sectors makes up the complete model that determines the feasibility of stover as a supplemental fuel.

Farm Sector

The farmer will not supply his stover to the power plant unless he is paid at least his opportunity cost. This is the break-even point of the farm sector. This cost is composed of the harvest cost, the storage cost, and the net value of the stover itself. The net value of stover is the nutrient content of stover, plus the value of stover for erosion control and livestock feed and bedding, less any reduced costs in tillage associated with stover removal.

It is difficult to quantify the value of stover as an erosion control material based upon the

available data. Schrader, Pesek, Schaller; and Gupta et al. argue that there is a safe limit of stover removal that leaves the soil intact depending upon the type of soil, the slope of the land, and the soil conservation practices. Consultation with agronomists and agricultural extension agents in the localities of the case studies (Ames, Iowa, and Peru, Indiana) was used to determine the total amount of stover that could be removed safely for feed, bedding, and fuel. The same consultations were used to determine the proportion of total stover needed for livestock feed and bedding. The maximum amount of stover available for use as a fuel is the difference between the total amount that can be safely removed and the amount needed for livestock feed and bedding adjusted for a machine harvest efficiency of 64%. This procedure implicitly assumes zero erosion control costs and with the machine efficiency adjustment provides a conservative estimate of available stover for energy. Assuming that farmers will not remove more than the surplus residue, the opportunity cost of the removed stover is the cost of the fertilizers (nitrogen, phosphorus, and potassium—N, P, K) it contains.

For the savings in reduced tillage, only stalk-chopping costs are considered. Plowing and discing costs may be reduced in some cases because of the removal of stover, but these savings are not considered to avoid overestimation of the feasibility of stover as a fuel.

Based on the foregoing considerations, the farm sector relationship is formulated as follows:

$$(1)\quad \text{Min } PsF/MBTU = CH + CS + NVS,$$

where Min $PsF/MBTU$ is minimum price the farmer can accept for the amount of stover that generates one MBtu of heat, CH is harvest cost for the amount of stover that generates one MBtu of heat, CS is storage cost for the amount of stover that generates one MBtu of heat, and NVS is net value for the amount of stover that generates one MBtu of heat, i.e., the savings of foregone chopping costs minus the fertility loss.

The most common types of equipment for harvesting stover in the north central region are the stacker, the large round baler, and loose chop. Farm sector costs are estimated for these three systems of stover harvest. Each system of harvest has different associated transportation and firing systems. Farm storage costs also differ with the harvest system. To identify the least-cost system, the stacker, the large round baler, and the loose chop costs are estimated and compared.

Power Plant Sector

A power plant will not use the corn stover as a fuel unless it costs the same or less than the cost of using coal per unit of heat value. The break-even point of the power plant sector is the maximum price the power plant can pay for stover. This maximum price is the cost of using coal less any costs associated with the use of corn stover in the power plant.

The cost of using coal is composed of the delivered cost of coal, the handling and processing costs, and the sulfur emission control costs (if any). The costs associated with the use of corn stover at the power plant are the necessary modifications of the boiler(s), storage, and conveying costs.[2] The maintenance and operating costs of these installations are also part of the costs associated with the use of corn stover as a power plant fuel. Based upon these costs, the relationship of the power plant sector is as follows:

$$(2)\quad \text{Max}PsP/MBTU = Pc + PRc + Ec - CUS,$$

where Max$PsP/MBTU$ is maximum price the power plant can pay for the amount of stover generating one MBtu of heat, Pc is price of coal per MBtu, PRc is processing costs of coal per MBtu, Ec is sulfur emission control costs per MBtu, and CUS is cost of using stover per MBtu. This is composed of capital costs (amortized using the flow method of capital depreciation), maintenance, and operation costs. The per unit capital cost assumes utilization of full modified boiler(s) capacity.

To conform to the EPA sulfur emission standards, the Ames, Iowa, power plant is blending high sulfur Iowa coal with low sulfur Colorado coal. The other case study (Peru, Indiana, power plant) would use the same

[2] Emission monitoring of refuse-derived fuel (RDF) and coal combustion at the Ames Municipal Power Plant by U.S. EPA showed mixed results. Particulate emissions both increased and decreased with increased percentage of RDF, depending on boiler unit and boiler load. No monitoring of corn stover combustion has been done. Thus, the RDF particulate results at Ames were the basis for assuming no additional costs would be incurred for particulate emission control with the combined combustion of corn stover and coal.

method if required to conform to the standards set for it. To impute the value of stover as a sulfur emission control material, a linear programming model is used. The model is solved with and without corn stover, assuming a zero price for corn stover. The solution is constrained by EPA-imposed sulfur emission standards, by a plant heat production constraint and by a maximum stover/coal-firing ratio for each MBtu of heat produced by boiler type.[3] The difference between the cost of the coal blend with and without the stover is the "shadow price" or the value of stover as a sulfur emission control material.

The general form of the model is as follows:

$$\text{Min } C = \sum_{i=1}^{n} X_i P_i,$$

subject to

$$\sum_{i=1}^{n} S_i X_i \leq S,$$

$$\sum_{i=1}^{n} H_i X_i = 1\ MBTU,$$

$X_1\ H_1 \leq .2\ MBTU/MBTU$-produced (suspension-fired),
$X_1\ H_1 \leq .5\ MBTU/MBTU$-produced (stoker-fired),

where Min C is minimum cost of the blend generating one MBtu of heat; X_i, amount of fuel i in pounds; P_i, price of fuel i per pound (price of corn stover assumed to be zero); S_i, sulfur dioxide content per pound of fuel i; S, sulfur standard set for the power plant (lbs. S_2O/MBtu); H_i, heat content of fuel i (Btu's/lb.); n, number of coal and stover fuels; and 1, corn stover.

Transportation Sector

Transportation of stover from the farm to the power plant could be handled several ways. The stover could be delivered to the power plant by the farmer or picked up at the farm by the power plant. In either case, a custom hauler could be used. If the stover is delivered to the power plant, the relevant transportation distance is the radius of the circle or "stover shed" from which enough stover can be collected to meet the power plant capacity or level of throughput.[4] In this case, the farmer at the margin will determine the price of stover and the farmers located closer to the plant will earn a rent. If the stover is to be picked up at the farm, the appropriate hauling distance is the weighted average distance from the stover shed to the plant. To present conservative estimates of feasibility in the initial analysis of the two case studies, it will be assumed that the stover is delivered to the power plant. In the subsequent sensitivity analysis, it will be assumed that the stover is picked up at the farm.

The other components of transport cost are the loading and unloading costs and the cost per loaded mile. The total transportation cost function is as follows:

(3) $TRPC/MBTU = LUC + CLM \times D,$

where $TRPC/MBTU$ is total transportation cost/ MBtu, LUC is the loading and unloading costs of the amount of stover that generates one MBtu, CLM is cost of hauling the amount of stover that generates one MBtu for one mile, and D is hauling distance required to meet plant capacity.

The Complete Model

The break-even point of the system is realized when the summation of the farm sector cost/MBtu and the transportation cost/MBtu is equal to the maximum price the power plant can pay for stover per MBtu.

(4a) $CH + CS + NVS + LUC + CLM \times D = Pc + PR_c + E_c - CUS$, or

(4b) $CH + CS + NVS + LUC + CLM \times D - Pc - PR_c - Ec + CUS = 0.$

If equation (4b) is less than or equal to zero, stover is assumed to be feasible as a coal supplement. If it is greater than zero, stover is infeasible at 1977 prices of coal.

Data Collection

Data on corn stover is available from the Stanford Research Institute (SRI) in *Crop, Forestry, and Manure Inventory for the United States.* Although this source contains detailed and comprehensive data on crop residues in

[3] Based on consultation with boiler engineers and power plant managers, the maximum stover/coal firing ratio is assumed to be 20/80 for the suspension-fired boiler and 50/50 for the stoker boiler.

[4] This analysis assumed that the power plant sector will operate at full estimated stover and coal combustion capacity. If this assumption is relaxed, the margin of the stover shed is where delivered price at the plant equals harvest and transport costs plus farm value of the stover.

the United States, it has some limitations, particularly regarding corn residue. The SRI data assumes 55% of the corn stover is fed to livestock. Consultation with agricultural extension agents in Story County, Iowa, and Lancaster County, Nebraska, and animal scientists and agronomists at Ohio State, Iowa State, and Nebraska Universities reveals that the amount of stover fed to animals in the Corn Belt probably does not exceed 10% of the stover produced annually. Calculating the maximum amount of stover that could be fed to the livestock in the north central states also showed that 55% is too high for most of the north central states. The SRI data has been adjusted, based upon the maximum quantity of stover consumable by livestock. This revision also overestimates the amount of stover fed to livestock but it is closer to reality than the SRI base data.

The estimates of the costs for the farm and transport sectors are developed primarily from custom rates. Custom rates are published annually by the Cooperative Extension Services of the land grant universities in the north central states. Table 1 presents the average custom rates for hay harvest and transportation for Indiana and Iowa. An effort was made to get the actual custom rates in the localities of the two case studies (Ames, Iowa, and Peru, Indiana) but such data were not available. However, the county extension agents in Story County, Iowa, and Miami County, Indiana, felt that the average custom rates were close to the custom rates in their counties.

The cost estimates for the power plant conversion for corn stover combustion were provided by Gordon Smith, a consultant engineer from Akron, Ohio, experienced in conversion of power plants to fire solid waste. Generally, the estimates reflect costs comparable to those encountered in modifying coal-burning boilers for firing solid waste with coal. Exceptions include addition of a grate to pulverized coal boilers and reduced processing costs due to the absence of metals in corn stover. Cost data on the processing of stover were provided by Farmhand, Inc., Jeffrey Manufacturing Company, and Battelle Columbus Laboratories. A different processing system was specified for each of the three harvest systems. Detailed capital and operating cost estimates for harvest, transport, processing, and plant modifications are developed in Abdallah (pp. 50–76).

Price of coal, type of coal, sulfur and Btu content of coal, and the EPA standards set for each case power plant were provided by the management of the two power plants analyzed and are summarized in table 2.

To attempt to apply the results of the two case studies to other power plants and associated stover sheds in the region, fifty-three power plants were randomly chosen from the power plant population in the north central states. Data on coal prices, custom rates, power plant stover capacity and availability were collected for each of the fifty-three power plants and associated stover sheds and are presented in Abdallah (pp. 170–73). This sample represents approximately 22% of the population of power plants in the region.

Results of the Ames Case Analysis

The Ames power plant is already converted to burn solid waste. It has two stokers and one pulverized coal boiler. To reduce the sulfur emissions of the high sulfur Iowa coal, this power plant is using low sulfur Colorado coal to conform to the EPA sulfur standards.

Table 1. Average Custom Rates in Indiana and Iowa for Three Harvest and Transport Systems, 1977

	Indiana			Iowa		
	3-Ton Stack $/Stack	Large Round $/Bale (1500 lbs.)	Loose Chop $/Ton	3-Ton Stack $/Stack	Large Round $/Bale (1500 lbs.)	Loose Chop $/Ton
Harvest	23.00	11.90	8.84	18.10	7.70	9.48
Transportation						
Loading and unloading	6.24	0.40	0.76	4.00	0.32	0.72
Cost/loaded mile	0.60	0.09	0.32	0.50	0.07	0.26

Sources: Purdue University and Iowa State University.

Table 2. Summary Characteristics of the Coal Used in Ames, Iowa, and Peru, Indiana, Power Plants, 1977

	BTU Content (Btu/lb.)	Sulfur Content (%)	EPA Sulfur Standard (lbs./MBtu)	Prices ($/ton)
Ames, Iowa[a]			5	
Iowa coal	9,345	5.5		17.71
Colorado coal	12,000	0.5		32.51
Peru, Indiana[b]			6	
Indiana coal	11,000	4.0		26.50
Colorado coal[c]	12,000	0.5		36.00

[a] Personal interview with power plant managers, summer, 1977.
[b] Personal interview with power plant managers, winter, 1977.
[c] The price of Colorado coal for the Peru, Indiana power plant is estimated based on discussion with three coal shipping companies located in Columbus, Ohio.

The stover combustion capacity of one of the stoker boilers is 150 tons per day. To compare the results of the analysis of the stoker boiler with the pulverized coal boiler, a 150 ton per day level of throughput also is used for the pulverized coal boiler.

Four scenarios are analyzed for this power plant: stoker boiler without emission control costs, stoker boiler with emission control costs (*Ec*), pulverized coal boiler without emission control costs, and pulverized coal boiler with emission control costs.

The farm, transportation, and power plant sector costs are estimated for each of the four scenarios. The cost of sulfur emission control is imputed using the linear programming model discussed earlier. The capital cost of modifying the power plant is amortized using 5%, 9%, and 13% interest rates as part of the sensitivity analysis. However, the 9% rate is assumed to be the most likely or appropriate rate of interest over the life of the project.

By adding the farm and transportation sector costs and subtracting the maximum price the power plant can pay, the feasibility of stover is determined. Table 3 summarizes the results of the break-even point analysis for the four scenarios considered for the Ames power plant (150 tons/day throughput) at the 9% interest rate on capital and 1977 prices of coal. A positive value reflects an economically feasible or "better than break-even" alternative.

Excluding the sulfur emissions control costs from the cost of using coal at the Ames power plant, corn stover is not feasible even for the least-cost harvest system (the stack) and the stoker boiler, which costs less to modify than the pulverized coal boiler. Including the sulfur emission control costs, the stack-harvested stover is feasible for both types of boilers (table 3). More detailed development of the Ames case results is presented in Abdallah (pp. 81–106).

Results of the Peru Case Analysis

This power plant has three pulverized coal boilers and uses Indiana coal which does not meet the EPA sulfur standards. The level of stover throughput estimated for the largest boiler is fifty tons per day. As with the Ames power plant, the analysis is conducted for the Peru case for the farm, transport, and plant

Table 3. Economic Feasibility of the Ames, Iowa, Power Plant (150 Tons/Day) Scenarios at 9% Interest and 1977 Prices of Coal

	Max. Power Plant Price—Farm and Transportation Costs in $/MBtu			
	Stoker Boiler		Pulverized Coal Boiler	
	Without Ec[a]	With Ec	Without Ec	With Ec
Three ton stack	−0.249	0.164	−0.292	0.101
Large round bale	−0.414	−0.001	−0.457	−0.139
Loose chop	−0.629	−0.216	−0.672	−0.470

[a] Ec refers to sulfur emission control costs.

sectors at three interest rates using 1977 prices of coal. Because this power plant has only pulverized coal boilers, only two scenarios are considered: pulverized coal boiler with and without sulfur emissions control costs.

Without sulfur emission control costs, stover is not feasible for this power plant at the 9% interest rate (table 4). The system also is not feasible or does not break even at 5% interest on capital. Including the sulfur emission control costs (assuming this power plant has to conform fully to EPA sulfur standards) the stack-harvested stover is feasible only if the interest rate on capital is 5%. At 9% interest on capital, it falls short of feasibility by \$0.018/MBtu, i.e., if this power plant used corn stover as a supplemental fuel, it would incur a loss of \$0.018/ton if it internalized the sulfur emission control costs and paid 9% interest rate on capital. More detailed development of the Peru case results is presented in Abdallah (pp. 106–21).

The main factors that contribute to the relatively higher feasibility of stover in Ames, Iowa, than in Peru, Indiana, are the lower custom rates and the lower per unit modification costs at Ames. Modification costs are lower at Ames because of the size economies of boiler conversion. The higher level of throughput at Ames yields a lower modification cost per unit of corn stover burned (\$0.295/MBtu) compared to Peru (\$0.476/MBtu) for the same type of boiler (pulverized coal) and the same rate of interest (9%). The per unit modification costs are more than one and one-half times higher at Peru. The economies of size are discussed further in the sensitivity analysis section which follows.

Table 4. Economic Feasibility of Peru, Indiana, Pulverized Coal Boiler (50 Tons/Day) Scenarios at 9% Interest and 1977 Prices of Coal

	Max. Power Plant Price—Farm and Transportation Costs in \$/MBTU	
	Pulverized Coal Boiler	
	Without Ec[a]	With Ec
Three ton stack	−0.318	−0.018
Large round bale	−0.751	−0.456
Loose chop	−0.786	−0.591

[a] Ec refers to sulfur emission control costs.

Sensitivity Analysis

Sensitivity analysis is performed on the major variables that affect the feasibility of stover as a fuel. Specific independent variable or parameter changes required for the system to break even are determined, holding all other parameters constant. The major variables are price of coal, custom rates, Btu content of stover, plant modification costs, level of throughput, changes in harvest technology, and hauling distance.

Independence of the major parameters can be assumed in the sensitivity analysis with the exception of level of throughput which may affect plant modification cost, hauling distance, and/or transport costs. Plant modification costs also might increase as the result of such things as rapid escalation of wages and older plant and equipment. Hauling distance may increase or decrease at a constant level of throughput due to variation in stover density. The price of coal, Btu content of stover, and harvest cost decreases from new technology all can be assumed independent. A separate sensitivity analysis is done on the interrelated variables or parameters.

Table 5 shows the independent variable or parametric changes for the break-even point to be realized at 9% interest on capital for the stack system of harvest at the Ames and Peru plants. The system is generally most sensitive to the independent variables of coal price, stover Btu content, and harvest cost.

For the Ames case to break even without emission control costs, the price of coal has to increase by 22%. If *Ec* are included, the price of coal can drop by 17% and the system would still break even (table 5). Without emission control costs, the Btu content has to increase by 26% before the Ames case can break even and by 25% for the Peru case to break even. If the higher estimate of the stover Btu content of 8000 Btu per pound (used by Starr and Benson) is used instead of 6500 Btu per pound, both cases would be nearly feasible even without including sulfur emission control costs at 1978 prices of coal.

If the harvest cost dropped by 54% (change in technology), both the Ames, Iowa, and Peru, Indiana, cases would break even without including *Ec* (table 5). Such a drop in harvest cost is not impossible. Stover might be combine-harvested with the corn grains in the same operation. This also could reduce the impact of the timeliness problem of stover harvest and fall plowing.

Table 5. Independent Variable Percentage Changes Needed for the Stack System to Break Even at 1977 Coal Prices and 9% Interest on Capital for the Two Case Studies

	Ames, Iowa (150 tons/day)				Peru, Indiana (50 tons/day)	
	Stoker Boiler		Pulverized Coal Boiler		Pulverized Coal Boiler	
Parameter	Without Ec	With Ec	Without Ec	With Ec	Without Ec	With Ec
	(%)					
Price of coal	+22[a]	−17[b]	+36	− 8	+25	+1.2
Modification costs	N.A.[c]	−70	N.P.[d]	−34	−66	−4
Stover Btu content	+26	−12	+36	− 7	+25	+1.2
Hauling distance	N.A.	+107	N.A.	+66	N.A.	−17
Harvest cost	−54	+ 35	−68	+22	−53	−3

[a] (+) refers to percent increase in a parameter needed for the break-even point.
[b] (−) refers to percent decrease in a parameter needed for the break-even point.
[c] N.A., not applicable.
[d] N.P., the break-even could not be obtained even if the parameter is equal to zero.

The system is least sensitive to variations in the hauling distance variable. The Peru case is not feasible regardless of whether the stover is assumed delivered at the power plant or picked up at the farm. The hauling distance can increase by 107% (up to 23.2 miles one way) and the Ames, Iowa, stoker boiler, including the emission control costs, still would break even. Without including the emission control costs, all the cases considered would not be feasible even if the hauling distance is zero.

Sensitivity analysis to test the impact of the size of boiler converted or level of throughput on the per unit cost of firing and transporting the stover (the scale effect) is reported in table 6. Five boiler sizes, or full capacity levels of throughput at 50, 75, 100, 125, and 150 tons per day of stover, are employed to show the scale effect for the Ames, Iowa, stoker boiler.[5] It is found that as the boiler size increases, the per unit modification cost decreases. However, as boiler size increases, the per unit transportation costs also increase. The optimum level of throughput increases with the rate of interest. It is found to be 100, 137, and 168 tons per day, respectively, at the 5%, 9%, and 13% interest rate on capital (figure 1).

The results of the sensitivity analysis and the sample of power plants ($n = 53$) can be utilized to get some notion of the potential of corn stover combustion with coal in steam-electric boilers in the north central states. Information for the sample plants on stover density, harvest and transport custom rates, coal

[5] Extrapolated estimates are made for two additional levels of throughput (175 and 200 tons/day).

Table 6. Stoker Boiler Capital, Maintenance, and Operating Costs and Stover Transportation Cost/MBtu for Five Boiler Sizes (for Stack System)—Ames, Iowa

Power Plant Stover Capacity (Tons/Day)	Required Distance (Miles)	TPC[c] Cost $/MBtu	*KC + MOP*[c] $/MBtu 5%	9%	13%	*TPC + KC + MOP*[c] $/MBtu 5%	9%	13%
50[a]	7.62	0.199	0.269	0.352	0.444	0.468	0.551	0.643
75[a]	9.04	0.217	0.244	0.310	0.334	0.461	0.527	0.551
100[a]	10.10	0.231	0.224	0.282	0.319	0.455	0.513	0.550
125[a]	10.92	0.242	0.206	0.251	0.306	0.448	0.493	0.548
150[a]	11.71	0.252	0.187	0.232	0.283	0.439	0.484	0.535
175[b]	13.85	0.280	0.151	0.210	0.310	0.431	0.480	0.521
200[b]	16.54	0.315	0.145	0.180	0.230	0.460	0.495	0.585

[a] Estimates are based upon the data collected for the Ames, Iowa, case study.
[b] The extrapolated estimates shown by the dotted lines of figure 1.
[c] *TPC* is transportation costs, *KC* is plant capital costs, *MOP* is plant maintenance and operating costs.

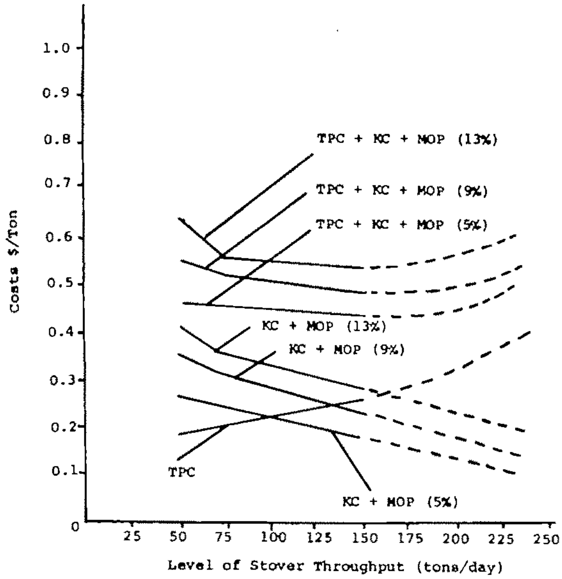

Figure 1. The relationship between the power plant modification and stover transportation costs and the level of stover throughput

prices, sulfur emission standards, boiler type, number and size, combined with the assumption that large multiple boiler plants can convert only part of their capacity to corn stover combustion provides some basis for extending the case study results. It would appear that from one-third to one-half of the coal-burning power plants in the north central states have more favorable, or comparable conditions, for feasibility of stover as a fuel to those of Ames, Iowa.

Assuming that one-half the power plants have more favorable, or comparable conditions, to Ames, Iowa, the proportion of corn stover that could be utilized economically in steam-electric power plants in the north central region could replace approximately 20 million tons of coal or 488 trillion Btu's per year. Although coal and oil are not perfect substitutes, this coal savings is equivalent to approximately 87 million barrels of crude oil per year. This is a large number, but it represents less than ten days of crude oil imports at current levels.[6]

[6] Additional potential exists in the numerous industrial and institutional coal-burning steam-generating boilers located in the north central states. Data are not as readily available on these installations, but in Ohio they are approximately ten times more numerous than coal-burning steam-electric boilers.

Summary and Conclusions

Because of the growing rate of energy consumption, the depletion of nonrenewable fossil fuels is inevitable. Renewable resources, such as biomass, are assumed to be more appropriate sources of energy if they are currently or potentially cost competitive. In this research, the economics of using corn stover as a power plant fuel to supplement coal is investigated in two case study steam-electric power plants: Ames, Iowa, and Peru, Indiana.

If the price of coal increases at a faster rate than the harvesting, transport, and firing costs of stover, the feasibility of corn stover as a fuel at small power plants similar to the Peru, Indiana, plant is foreseeable in the near future. Assuming sulfur emission standards are required to be met, the Ames, Iowa, case is economically feasible at current prices.

The sulfur emission control costs proved to be important for the economic feasibility of stover. If the sulfur standards become more stringent and are more rigorously enforced, stover feasibility would improve. If the proposed requirement of installing stack scrubbers in all the coal-using power plants is imposed, the value of corn stover as a sulfur emission reducing material probably would decline.

The results of the sensitivity analysis reveal that among the independent variables or parameters, the price of coal (including the sulfur emission control costs or higher priced, low sulfur coal), the Btu content of stover and the harvest cost are important determinants of feasibility of stover as a power plant fuel. The optimization of stoker boiler size or level of throughput and the associated transport costs for the Ames case occur somewhere between 100 and 168 tons of stover per day, depending on the rate of interest assumed.

The stack system of harvest proved to be the least-cost system of harvesting and firing the corn stover. The large round bale system involves lower transport cost than the stack system but the stack system is much less costly to harvest and fire at the power plant.

More research is needed on the potential for corn and other crop residues as well as solid waste and forest biomass combustion, particularly in coal-burning industrial and institutional boilers—probably more numerous than steam-electric plants. This work also should attempt to determine any potential net liquid

fuel savings from reduced transport of low sulfur western coal to meet emission standards. Preliminary assessment of these savings looks promising. Further research also is needed on the economic feasibility as well as the energy balance of alternative uses of corn stover and other crop and forest biomass for methane, ethanol, and other thermochemical and biological conversion products. The recent discovery at Purdue University of a more efficient solvent process for the conversion of cellulosic material, such as crop residue, to ethanol (a liquid fuel) may be promising in this regard (Tyner and Bottum).

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References

Abdallah, Mohammed. "Economics of Corn Stover as a Coal Supplement in Steam-Electric Power Plants in the North Central States." Ph.D. thesis, Ohio State University, 1978.

Benson, Walter. "Biomass Potential from Agricultural Production." *Biomass—A Cash Crop for the Future?* Conference Proceedings, Midwest Research Institute and Battelle Columbus Laboratories, Kansas City, Mo., 2–3 Mar. 1977.

Buchele, Wesley. "Direct Combustion of Crop Residues in Furnace and Boilers." *Biomass—A Cash Crop for the Future?* Conference Proceedings, Midwest Research Institute and Battelle Columbus Laboratories, Kansas City, Mo., 2–3 Mar. 1977.

Cooperative Extension Service. "Estimated 1977 Iowa Farm Custom Rates." Iowa State University, 1977.

Cooperative Extension Service. "Indiana Custom Rates for Power-Operated Farm Machines." Purdue University, 1977.

Dugan, R. Patrick. "Microbiological Desulfurization of Coal." Dep. Microbiology, Ohio State University, Jan. 1977.

Gupta, S. C., W. E. Larson, L. D. Hanson, and R. H. Rust. "Area Delineated of Possible Crop Residue Removal for Bioenergy in Four Minnesota Counties." *Soil Erosion: Prediction and Control.* Ankeny, Ia.: Soil Conservation Society of America, 1976.

Hitzhusen, F., R. Shenk, and R. Rivet. *Economics of Nonmetro Solid Waste Resource Recovery in the North Central Region.* North Cent. Rgnl. Ctr. for Rural Develop. Res. Monograph, Iowa State University, Feb. 1979.

Roller, L. Warren et al. *Grown Organic Matter as a Fuel Raw Material Resource.* Agr. Eng., Ohio Agr. and Develop. Ctr., 1975.

Shrader, W. D., John Pesek, and F. W. Schaller. "Crop Rotation, Facts and Fiction." *Iowa Farm Science* no. 9(1962), pp. 6–9, Iowa State University.

Starr, J. Patrick. *The Development and Assessment of Strategies for Firing Crop Residues in Minnesota.* Dep. Mechan. Eng., University of Minnesota, 1976.

Stanford Research Institute. *Crop, Forestry, and Manure Residue Inventory.* Menlo Park, Calif.: Continental United States, June 1976.

Tyner, Wallace, and J. Carroll Bottum. "Agricultural Energy Production: Economic and Policy Issues." Dep. Agr. Econ. Statist. Bull. No. 240, Purdue University, Sep. 1979.

U.S. Environmental Protection Agency. *Evaluation of the Ames Solid Waste Recovery System, Part 1—Summary of Environmental Emissions: Equipment, Facilities and Economic Evaluations.* Cincinnati, O.: EPA-600/2-77-205, Municipal Environmental Research Laboratory, Nov. 1979.

European Community Agriculture and the World Market

Alan Swinbank

The European Communities' common agricultural policy is more complex than some studies would indicate. Not only do the member states succeed in maintaining nationally preferred price support levels through the use of green currencies and monetary compensatory amounts, but the protective mechanisms applied have a differential impact on some commodities and some supplying countries. The introduction, in 1979, of the European Monetary System had repercussions for the agricultural sector, including the use of a new unit of account.

Key words: common agricultural policy, import levy, unit of account.

For the last twenty-five years economists, civil servants, and politicians have been concerned with the impact of the common agricultural policy (CAP) of the European Communities (EC) on the operations of the world market. Unfortunately, it is tempting to treat the CAP as if it were a single policy applied in a uniform manner in all the member states of the EC. This is an oversimplification which could lead to serious misinterpretation of the CAP. In fact, as this article will attempt to point out, foreign suppliers of temperate zone agricultural produce face at least three distinct forms of protective mechanism. Furthermore, the concept of common support prices within the EC is an illusion; for many commodities there are seven regional price zones. That common EC farm prices do not exist has received extensive attention in the European literature; that not all products or suppliers face the same protective mechanism or degree of protection has received little attention even in Europe. A noticeable exception is Harris, who has attempted to document the various trading relationships. In describing these three "faces" of the CAP, a number of topics worthy of further research will be identified.

The article will be limited to a consideration of temperate zone agricultural products, or products that effectively compete with the output of European temperate zone agriculture. It will not deal with the particular problems of Mediterranean zone produce—issues that are particularly pressing, given the forthcoming enlargement of the EC to encompass Greece and the proposed enlargement to include Portugal and Spain—nor the hierarchy of tariff and other trade concessions conceded by the EC on various tropical products to particular less developed countries.

During 1979 a European Monetary System (EMS) was introduced which will in time modify the details of the CAP, if not its character. In a concluding section, an attempt will be made to sketch the impact of EMS on the farm sector.

The Exchange Rate and Agriculture

In North America, concern has been expressed about the impact of the exchange rate on the farm sector. Thus, Schuh was concerned about the impact of an over-valued dollar on the adjustment problems of U.S. agriculture. An implicit assumption in his analysis was that the farm sector was in some sense more responsive to changes in world market prices—and hence, to manipulations of the exchange rate—than were other sectors of the economy. Thus, if it could be shown that various policies had resulted in an over-valuation of the U.S. dollar, it would follow that there had been a differential impact on the farm sector (in comparison to the other sectors of the economy) which would tend to depress farm earnings and output.

In the EC, concern has also been expressed about the response of farm and food prices to

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exchange rate changes; but in this instance the responsiveness was not due to the inherent characteristics of the economy, but to the mechanism of the CAP price support system. One of the basic principles of the founding fathers of the EC was that free trade should exist within the Community. However, it was also decided that for many farm products—including cereals, sugar, dairy products, beef, and pigmeat—a Community-wide price support system should exist maintained by the paraphernalia of threshold (minimum import) prices and intervention (public purchase) prices. Threshold prices are fixed above intervention prices so that under most market conditions domestic produce enjoys a price advantage over potential imports.

In August 1969, only two years after common EC prices had been established for cereals, the French franc was devalued. If common support prices were to be maintained, then the franc price would have had to increase by the full extent of the devaluation. The effect would have been as if France had faced a perfectly elastic foreign demand for her farm produce, so that on devaluation the domestic price would rise by the full extent of the currency change, whereas, in practice, most sectors of the French economy would face a smaller price effect.

The French government was unwilling to accept a sharp rise in the cost of food and so maintained the level of support at the franc prices prevailing before the devaluation. Common prices no longer existed and the support mechanism in the other member states had to be bolstered by border taxes on exports from France to them, with subsidies on imports into France. These border taxes and subsidies are now known as monetary compensatory amounts (MCAs). France had isolated the farm sector from exchange rate change: in effect, the pre-devaluation exchange rate had continued to be used in the farm sector to determine national price support levels. Thus the "green franc" was developed.

Later in the same year (October 1969) the West German mark was revalued. This posed similar problems for the West German government, but in this instance government policy was directed to avoiding a fall in German farm product prices. Thus a "green mark" came into being and monetary compensatory amounts were levied on German imports and paid on German farm exports.

Despite the disruption to common pricing, both France and West Germany did at the time agree to a return to free intra-Community trade. Thus France agreed to eliminate her green currency over a two-year period. For Germany it was decided that the losses experienced by farmers caused by an early return to common pricing would be compensated in various ways, including a temporary rebate on value-added tax. A select committee of the British House of Lords recently revealed that German farmers would in fact continue receiving some benefit from this concession on value-added tax until the end of 1980 (House of Lords, p. 84).

The dollar "crisis," and subsequent Smithsonian agreement of 1971, exacerbated the problem of trying to maintain common CAP pricing because intra-EC exchange rate movements were evident. Indeed throughout the 1970s intra-EC exchange rate movements have continued. Governments have attempted to maintain stability in farm and food prices; in some cases they have attempted to protect consumers from the consequences of devaluation (e.g., the United Kingdom) or farmers from revaluation (e.g., West Germany). There have been some "devaluations" and "revaluations" of green rates but these have not matched the evolution of the market exchange rates. Consequently, there now exist seven price zones for farm products within the EC, the three Benelux countries having maintained a common level of price support. The German price level has consistently been at the top of the price hierarchy; often 40% above the British price level at the bottom. Table 1 gives an indication of the relative levels of CAP price support in July 1979; the ordering is fairly constant through time, but the absolute levels do vary. The particular figures shown

Table 1. Index of CAP Support Prices, July 1979

Country	
West Germany	119.2
Benelux	110.6
Denmark	107.5
Ireland	105.9
France	102.2
Italy	100.7
United Kingdom	100

Note: Based on MCA percentages applied for most CAP products in July 1979: immediately following final agreement on the 1979/80 price package.

reflect a considerable strengthening of sterling during the preceding weeks.[1]

It has been explained that for many CAP commodities a uniform level of EC price support does not exist; instead there are a number of different national support levels. However, the fiction is maintained that EC prices are common through the device of fixing them in units of account. The unit of account is not a currency, but merely an accounting unit. To convert these "common" prices into national monies the green conversion rates, referred to above, are utilized. Thus, a green conversion rate is an expression relating so many units of a national currency in terms of units of account; and it is because these green conversion rates do not correspond to the market cross-rates between the currencies of the EC member states that different price levels result and MCAs are necessary. At the annual farm price review, ministers are concerned with the level of common prices fixed in units of account and with the green conversion rates for their respective countries (Harris and Swinbank). The unit of account prices determine the relative prices of the different commodities in each of the member states while the green conversion rate determines the absolute level of all prices.

Variable Import Levies and Export Subsidies

To ensure that minimum import prices are respected, variable import levies are imposed. For some products, such as cereals and sugar, these vary on a day-to-day basis, whereas, for other products, the levies are normally fixed less frequently (fortnightly for dairy products, monthly for processed products, and quarterly for pigment, eggs, and poultry meat). Whatever the details of the system the intention is the same: to maintain a constant level of price in each of the price zones regardless of developments on the world market. To permit EC produce to be marketed competitively on world markets, variable export subsidies may be granted.

The levy, or subsidy, will of course differ depending upon the EC member state with which the third country is trading. The net tax or subsidy is made up of two elements: a uniform EC levy or refund which bridges the gap between the world price level and the (largely fictitious) common EC price level, to which is either added or subtracted the same MCA that is applied in intra-community trade. In the case of West Germany this MCA would be an addition to an import levy (if applicable), whereas in the case of the United Kingdom it would act to reduce such an import levy.

This CAP support mechanism, which applies to many farm products, has two consequences for the world market. Many authors have commented that CAP price levels are maintained above the world market price. It is recognized that a relaxation of the price support mechanism within the EC would result in a greater import demand for agricultural produce and thus there would be a tendency for world market prices to rise. Nonetheless, many authors believe that EC price support levels are maintained above the long-run equilibrium level of world market prices and consequently that resource misallocation occurs. A number of authors (for example, Sampson and Yeats) have attempted to measure the effective rate of protection for EC agriculture. However, the protection afforded is variable, not fixed. Thus, even if it were established that the average effective rate of protection for some particular commodity were $x\%$ in some historic period, economists would still have difficulty comparing this with an effective rate of protection of $y\%$ (based on fixed tariffs) on another product.

From a theoretical, and a practical, point of view, the stability of CAP prices—whatever their level—is probably more significant. The nature of the variable import levy and export subsidy system is to maintain unchanged the pattern of EC production and consumption whatever the developments on the world market, even if the supply and demand fluctuations originate within the EC. Even when world market prices exceed EC prices, stability in EC production and consumption might be maintained because variable export taxes can be imposed and—in the case of sugar in 1974–75—variable import subsidies. However, it should be noted that the policy is not exactly symmetrical and the CAP is far more successful in maintaining stability of prices when the world market price lies below EC prices than in the contrary case.

The consequence of the policy—as Johnson noted—is that the EC tends to avoid any share in the burden of accommodating shortages and

[1] A large amount of detail has been omitted from this history, and some events are compressed into one. For a faithful history, see Irving and Fearn; for an analysis of the effect of MCAs on EC agriculture, see Heidhues et al., and Swinbank.

gluts in the world economy. A subset of the world's population must accommodate these changes, and the resulting world market price fluctuations will be greater than they would be if European producers and consumers were involved. Indeed, Josling has shown that if a number of major producing and consuming regions in the world adopt similar measures the level of the world market price could be indeterminate unless stockholding proved to be a significant activity.

It is often asserted that the world market is residual, and therefore unrepresentative, and to support this view the small proportion of production entering into world trade is cited. However, some support policies divorce the domestic market from changes on the world market (e.g., the CAP's variable import levies), whereas others allow domestic producers and consumers to react to changes on the world market (as with tariffs—ad valorem or specific—provided they are not prohibitively high).

On closer examination it might be found that certain world commodity markets are more representative than is commonly supposed because the particular form of protection adopted does permit the transmission of price signals across national boundaries. Thus, the logic of the Schuh thesis is that price formation for farm produce within the United States, and on the world market, is intimately linked. It also should be recognized that the situation is not static. Notwithstanding export taxes and (for sugar) import subsidies it is probable that certain regions of the EC—if not all member states—effectively entered the world market in the commodity boom of the early 1970s.

GATT Bindings on Oilseeds, Manioc, and Sheepmeat

There is a substantial trade in temperate zone (or temperate zone competing) products that escape the variable levy system and so provide a linkage between the EC market and the world market. For various reasons the EC entered into the General Agreement on Tariffs and Trade (GATT) bindings at the time of the Dillon round negotiations such that oilseeds, oilseed products, and manioc enter the EC at zero or very low tariffs and sheepmeat is subject to a 20% ad valorem tariff. It is sometimes reported that the EC much regret these bindings, and in the past there have been various attempts to tax imported vegetable oils. Recently it has been reported that in the future Thailand (the principal supplier) will voluntarily limit the shipment of manioc to the EC.

Commentary on these major exceptions to the CAP price support mechanism has concentrated on the lesser degree of protection afforded these products. Thus the EC's cereals policy is said to be under threat because of the use of cheap oilseed meal and manioc imports in animal feed, and the massive increase in shipments of soya from the United States and manioc from Thailand are cited to support this view. Certainly in the Netherlands feed compounders have made increasing use of these products. Similarly, the EC's dairy policy is said to be under threat on two fronts: cheap oilseed cakes stimulate milk production but skim milk faces competition as an animal feed from soya meal, and butter faces competition from vegetable oils in the form of margarine. Olive oil—another CAP-supported product—also faces stiff competition from vegetable oils. The conclusion that is drawn is that—compared to a free trade model—consumption of these commodities is stimulated in the EC and likewise their production in third countries.

However, one topic which has not been explored is the linkage these products provide between the world market and the EC market. The EC market price for soya rises and falls in response to changes on the world market, and thus the world market price does help determine the EC consumption of soya. But the linkage could well be perverse.

Suppose the world grain supply were to fall, thus driving up world market prices. The CAP price mechanism for cereals would ensure that EC prices remained unchanged, and thus the level of cereal consumption would be maintained whereas in other parts of the world it would fall. Livestock producers in those third countries would tend to switch from cereals to cereal substitutes, such as soya and manioc, and drive up their price. However, this price change would be felt within the EC; it would tend to raise the price of cereal substitutes in relation to cereals and so stimulate the consumption of cereals as animal feed. In Europe there would be a tendency to increase the consumption of cereals, whereas the rest of the world would be limiting consumption to match the available supply.

Sugar and New Zealand Butter

The entry of the United Kingdom into the EC in 1973 posed a number of problems for third country suppliers of farm products, particularly if those products were to be subject to the CAP price support mechanism which is operated to ensure that EC suppliers have first preference on the market. As part of the agreement reached at the time of the United Kingdom's accession, two major exceptions to this rule were agreed. The first was that Commonwealth sugar producers should have a guaranteed price and quantity in the British market. That agreement subsequently was amended to include a number of other less developed countries, and it now provides for the purchase by any member state, at a fixed price, of 1.3 million tons of white cane sugar per annum; more than 10% of EC consumption. Van Kempen recently has concluded an interesting study which deals with sugar in more detail than the following paragraphs, but in a similar way.

The second was to allow the United Kingdom to purchase from New Zealand specified quantities of butter and cheese, at a fixed price, up until the end of 1977. With a change of government in the United Kingdom in 1974, a renegotiation of the terms of entry ensued. This resulted in an extension of the agreement for butter, but not for cheese, until the end of 1980. New Zealand butter currently supplies more than 25% of the British market. As a result of the Tokyo-round negotiations, New Zealand (together with Australia and Canada) again will have access to the EC market for specified quantities of cheese at a given price; and the EC Commission has proposed to the Council that the agreement on New Zealand butter be extended beyond 1980.

The price guarantees involved are somewhat complex and warrant further attention. When the initial agreement on New Zealand dairy products was being concluded, New Zealand and Britain asked that the price guarantee be in terms of pounds sterling. The EC Commission insisted that this could not be the case, and that the price guarantee would be in terms of units of account. Equally, when the present sugar agreement was being drawn up, the guarantee was again concluded in units of account. In retrospect, these decisions can be seen as being highly advantageous to the supplying countries because the unit of account had been defined in such a way that it has increased in value against sterling.

In the 1960s, when the CAP was being assembled in a period of exchange rate stability, the unit of account was given the same gold value as the U.S. dollar. The devaluations of the dollar against gold in 1971 and 1973 were thus treated as devaluations against the unit of account. However, in 1973 a number of EC currencies began a joint float against the dollar (and other world currencies); and to maintain the European character of the unit of account, its value was linked to the joint float currencies. The introduction of the European Monetary System has involved certain modifications as outlined below.

As the joint float currencies floated against the dollar, so did the unit of account. The dollar value of the unit of account is tabulated in table 2. As the years have gone by, a number of different units of account have been defined. The one that is tabulated here, the EUR, is sometimes referred to as the agricultural unit of account. If all green conversion rates had been fully "devalued" or "revalued," they would have had these dollar values. In the next section the European unit of account (EUA) and the European Currency Unit (ECU) will be discussed. It can be seen from table 2 that since 1973 the dollar value of the EUR has varied considerably, depending upon the relative weaknesses and strengths of the dollar and the European joint float currencies on world money markets. The weakness of the dollar in relation to the EUR in 1978 is particularly evident.

The dollar value of the price guarantees to New Zealand and the sugar suppliers reflected the changing value of the EUR. The price guarantee has two parts: first, the market price in the United Kingdom where the product must compete with EC supplies; and second, an MCA subsidy paid on import to compensate for the fact that sterling had depreciated against the EUR.[2] Thus, instead of an unchanged guarantee in sterling, the sterling equivalent in fact increased as sterling fell against the EUR. In table 3 an attempt has been made to tabulate the impact of the price guarantees on the unit earnings.

In columns a and d of table 3 it is indicated that the EC in fact has increased the price guarantee for both products over the years, though it is widely reported that a deal was negotiated with New Zealand in 1976 which

[2] In the case of butter the New Zealanders themselves undertake shipment to the United Kingdom, but the sugar producers are in a weaker position in that they rely on the sugar traders to pass back the import subsidy.

Table 2. U.S. Dollar Value of the EUR

Month	1973	1974	1975	1976	1977	1978
January	1.09	1.14	1.36	1.24	1.33	1.47
February	1.15	1.18	1.39	1.25	1.32	1.50
March	1.22	1.22	1.41	1.24	1.33	1.53
April	1.21	1.26	1.38	1.25	1.34	1.52
May	1.23	1.29	1.39	1.25	1.34	1.47
June	1.30	1.27	1.39	1.23	1.35	1.49
July	1.37	1.28	1.32	1.23	1.37	1.50
August	1.32	1.25	1.27	1.25	1.37	1.54
September	1.32	1.23	1.24	1.28	1.35	1.56
October	1.33	1.26	1.25	1.31	1.37	1.66
November	1.26	1.29	1.25	1.32	1.38	1.60
December	1.21	1.31	1.24	1.34	1.43	1.61

Source: Statistical Office of the European Communities.

involved a higher price in exchange for a smaller quantity. Over the period in question, sterling has fallen in value in relation to the unit of account, and so the sterling price guarantees from the British market have evolved as in columns b and e. In columns c and f, the U.K. retail price index is tabulated. It will be seen that the sterling price guarantees have largely kept up with the rate of inflation in the United Kingdom, although the strength of sterling in 1979 has reversed that trend. It is of course true that these countries will have transport costs to pay, will not wish to purchase only British goods, and will not wish to purchase the range of goods represented in the U.K. retail price index; but as a first approximation, it does appear as if the price guarantees maintained their real value until early 1979.

An assessment of the benefits (or costs) of the EC's import concessions to the various sugar producers and New Zealand would have to measure the impact on the total export earnings of these countries for the products in

Table 3. Indices of Sugar and New Zealand Butter Price Guarantees (in Units of Account and Sterling) and of the U.K. Retail Price Index

	New Zealand Butter			Sugar		
	Price Guarantee Index			Price Guarantee Index		
	Units of Account	Sterling	U.K. Retail Price Index	Units of Account	Sterling	U.K. Retail Price Index
	a	b	c	d	e	f
Feb. 1973	100	100	100			
July 1973	100	112.5	104.2			
Jan. 1974	100	106.7	111.2			
July 1974	100	111.3	122.0			
Jan. 1975	118.0	142.1	133.4			
July 1975	118.0	148.5	154.1	100	100	100
Jan. 1976	139.2	177.2	164.5	100	101.2	106.8
July 1976	139.2	200.1	173.9	104.6	119.5	112.9
Jan. 1977	139.2	225.0	191.8	104.6	134.4	124.5
July 1977	139.2	233.4	204.5	106.7	142.2	132.7
Jan. 1978	153.2	242.6	210.8	106.7	134.3	136.8
July 1978	153.2	253.4	220.4	108.9	143.2	143.0
Jan. 1979	153.2	262.2	230.5	108.9	148.1	149.6
July 1979	153.2	236.9	254.9	110.6	135.9	165.4

Source: Columns *a* and *d* calculated from EC Regulations; columns *b* and *e*: as *a* and *d* but with EUR/ECU sterling series as supplied by the Statistical Office of the European Communities; columns *c* and *f*: Central Statistical Office (U.K.)
Note: Until March 1979, the price guarantees (columns *a* and *d*) were fixed in EUR, but in July 1979 in ECU.

question, not just the earnings on sales to the EC. Deductions would have to be made for transport costs because the guarantees apply in EC ports, and then the real purchasing power of the net export earnings assessed. Many of the sugar-producing countries, and New Zealand, sell substantial quantities of produce on world markets. If the EC subsidizes the export of some quantity of the produce, and so depresses world market prices, then it is, in effect, reducing the value of the price guarantees offered to the sugar-producing countries and New Zealand.

Table 4. The Composition of the European Unit of Account (EUA) and Subsequently the European Currency Unit (ECU)

Currency	Number of Currency Units Making Up the Unit of Account
West German mark	0.828
French franc	1.15
British pound	0.0885
Italian lira	109.0
Dutch florin	0.286
Danish krone	0.217
Belgian franc	3.66
Luxembourg franc	0.14
Irish punt	0.00759

Source: *Official Journal of the European Communities*, C21, pp. 4–5, 30 Jan. 1976.

Units of Account and the European Monetary System (EMS)

As the 1970s progressed, exchange rate movements within the EC led to pressure on three fronts. First, as we have seen, the concept of common prices within the CAP was shattered. Second, the definition of the unit of account proved to be too inflexible to absorb the changes taking place; and so, in 1975, a new unit was introduced: the European unit of account (EUA). Finally, the Europeans' aspiration for economic and monetary union, which had seemed to be receding, was revived in 1978, when a new political initiative was launched. This led to the establishment of EMS in the spring of 1979.[3] These three interrelated topics each have some significance for the foreign observer of EC agriculture.

The EUA was an attempt to define an EC measure which would reflect the changing values of member states' currencies, weighted in some appropriate fashion. It is literally a "basket" of currencies as is shown in table 4. Each of these constituent parts are valued in terms of Belgian francs on a daily basis thus giving the EUA's value in Belgian francs. Subsequently, the value of the EUA in terms of any other world currency can be determined.

The first sphere of EC activity in which the EUA was used concerned various measures associated with the EC-ACP (African, Caribbean, Pacific) convention of Lomé. In January 1977, the Statistical Office of the European Communities, in its publications, began using this new unit. For a two-year period (1975–76) the EUR had been used in statistical series; and prior to that the unit of account data published by the Statistical Office had been derived from national price data using the pre-Smithsonian IMF (International Monetary Fund) par values. Although the Statistical Office did, of course, revise the entire series of price data, subsequent editions of a particular publication contain the same series in a different form.

An appreciation of the confusing array of units of account perhaps can be gleaned from the following example. If, in December 1978, the intervention price of a particular product had been 100 units of account, this would have been equivalent in the United Kingdom at the then green rate to £63.42. Translated back into a statistical series, this would have become either 78.01 EUR or 94.39 EUA. Great care always should be taken, when using price statistics, that the units of account are properly defined and are consistent with other price data.

The decision to inaugurate EMS, on the one hand, implied the demise of the joint float (and hence the EUR) and, on the other, gave a central role to the EUA (rechristened the European currency unit—ECU). Thus the debate, which had continued for some time as to whether the EUA should be introduced into the agricultural sector, was brought to a conclusion. There were in essence two features of the new unit of account which caused problems for the CAP. The EUA (or ECU as it was now known) had a lower value than the EUR and so, if it had been introduced on a one-for-one basis, the theoretical "common" price level would have been correspondingly reduced. There was at no time any real intent that national price levels would be changed,

[3] The provisions of EMS were briefly described in the *Economist*, 17 March 1979.

for green conversion rates would continue to be used as before. However, such a change would have altered the basis for calculating monetary compensatory amounts because, for example, the German price level would then have been much further away from, and the British closer to, the "common" price level. This difficulty was overcome by applying a coefficient to both prices and green conversion rates so that there was no net change. (The coefficient was 1 EUR = 1.208953 ECU.)

The second difficulty arises from the fact that, over time, the "basket" unit of account is liable to be a weaker measure of value than the EUR. This is thought to be the case because the EUR was defined in terms of currencies which in the past have tended to appreciate on world currency markets, whereas the ECU is composed of a basket of all EC currencies, some of which in the past have tended to depreciate. This has led to the fear that CAP price levels might be eroded over time unless offset by corresponding increases in the common price level. It is probable that EC farm groups will be well able to defend their own interests; but the question does arise as to what in practice will happen to the price guarantees for imported dairy products and sugar. It is not possible to predict with any degree of certainty how the ECU will perform in relation to the EUR, or how generous (or parsimonious) the EC will prove to be in revising price guarantees to overseas suppliers.

These difficulties were complicated by a French demand that the introduction of EMS should herald the progressive dismantling of the MCA system and a genuine return to common CAP prices. The reluctance of the other member states to accede to this demand resulted in the delayed inauguration of the new currency system. However, it remains to be seen whether the compromise agreed upon will have any significant effect on CAP pricing. EMS is much less than an economic and monetary union; it is more akin to a European Bretton Woods system with fixed but adjustable exchange rates. It well may lead to a more stable monetary environment in which the day-to-day problems of running the CAP are reduced; but as yet it does not imply the convergence of economic performance which many observers would view as a necessary condition for return to common CAP pricing.

Conclusions

In this essay an attempt has been made to show that the EC's CAP has many facets, all of which impinge upon third country suppliers and the world market. In particular, three "faces" of the CAP have been identified: the archetypal system of variable import levies and export subsidies; the particular regime applying to oilseeds, manioc, and sheepmeat; and the price guarantees to certain overseas suppliers of dairy products and sugar. It is hoped that sufficient material has been documented to show that studies of the CAP should pay attention to detail.

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References

Harris, S. *The World Commodity Scene and the Common Agricultural Policy.* Wye, England: Centre for European Agricultural Studies, 1975.

Harris, S., and A. Swinbank. "Price Fixing under the CAP: Proposition and Decision. The Example of the 1978/79 Price Review." *Food Policy* 3(1978):256–71.

Heidhues, T., T. E. Josling, C. Ritson, and S. Tangermann. *Common Prices and Europe's Farm Policy.* London: Trade Policy Research Centre, 1978.

House of Lords Select Committee on the European Communities (Great Britain). *EEC Farm Prices 1979/80,* 19th rep., sess. 1978–79, HL 127. London: Her Majesty's Stationery Office, 1979.

Irving, R. W., and H. A. Fearn. *Green Money and the Common Agricultural Policy.* Wye, England: Centre for European Agricultural Studies, 1975.

Johnson, D. Gale. "World Agriculture, Commodity Policy, and Price Variability." *Amer. J. Agr. Econ.* 57(1975):823–28.

Josling, T. E. "Government Price Policies and the Structure of International Agricultural Trade." *J. Agr. Econ.* 28(1977):261–77.

Van Kempen, W. A. C. *Analysis of the Conflicts within the Lomé Sugar Protocol.* M.S. thesis, University of Reading, England, 1978.

Sampson, G. P., and A. J. Yeats. "An Evaluation of the Common Agricultural Policy as a Barrier Facing Agricultural Exports to the European Economic Community." *Amer. J. Agr. Econ.* 59(1977):99–106.

Schuh, G. E. "The Exchange Rate and U.S. Agriculture." *Amer. J. Agr. Econ.* 56(1974):1–13.

Swinbank, A. *The British Interest and the Green Pound.* Reading, England: Centre for Agricultural Strategy, 1978.

Price Behavior on a Declining Terminal Market

William G. Tomek

The relationship of prices of choice steers on the Denver terminal market to comparable prices on the Omaha market apparently was influenced by the sharp decline in saleable receipts in Denver. But price effects of the volume of trading were measurable only when the volume in Denver became extremely small in 1967 and 1968. These results are consistent with defining a thin market place by using sampling concepts. Some subtleties of using Chebyschev's inequality to define a thin market are discussed.

Key words: Chebyschev's inequality, markets, price discovery, sampling, steer prices, thin markets.

Thin markets may create problems in pricing farm products. One concern is that a small volume of trading at a central market place can result in price behavior not warranted by economic conditions. Moreover, deliberate manipulation of prices is more feasible with a small volume. If the central market quotations are used as base prices in other transactions, the problems of unwarranted or manipulated prices acquire increased economic importance.

Research and writing on thin markets can be categorized under five questions. First, what is a thin market? Second, why do markets become thin? Third, if a market becomes thin, what are the consequences, if any, for price behavior? Fourth, if price behavior is influenced, what is the mechanism or linkage between market volume and price behavior? Finally, if thin markets have adverse consequences, what solutions exist for the problem? Although a considerable general literature exists on thin markets (e.g., Hayenga), there is little specific information or empirical evidence on these questions. In this context, this paper has two objectives: to develop a more precise definition of thinness and to investigate the effects on price behavior of a declining volume of trading on a central market. In addition, the linkage between volume and price behavior is discussed briefly.

The empirical application is for choice steer prices in Denver, a terminal market that declined and disappeared. Steer prices in other locations are used as a standard of comparison. This paper, however, is essentially a search for hypotheses and an exploration of methods, and the empirical results should not be interpreted as definitive conclusions about price behavior on thin markets.

Defining and Analyzing Thin Markets

A major concern about thin markets is that the number of transactions (per unit of time) is so small that "unwarranted" price behavior occurs. The warranted price is usually defined in terms of the perfect competition norm. Prices may deviate from the norm because of deliberate manipulation or poor information. The issue of manipulation, however, is difficult to analyze with the data typically available. Observations on the actions and motives of individual traders are probably needed.

The issue of poor information perhaps can be analyzed with existing, secondary data. A declining volume of transactions implies less information and perhaps lower quality information. In a perfect market, a single equilibrium price exists for a given quality product at one location at a point in time (say, a day). A single transaction price, however, contains

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some error relative to the unknown equilibrium; the error may be large or small; the magnitude is unknown. An increase in the number of transactions within the time period increases the information available. Conversely, as volume declines, the quantity of information declines.

Information may be defined statistically as the reciprocal of the variance. If, as is assumed below, the average of transactions prices is an estimate of the true equilibrium price, then the variance of the mean of transactions prices decreases as the number of transactions increases (but see note 1). In this sense, the intuitive notion that fewer, publicly reported prices reduce information is consistent with statistical theory.

In addition, the quality of information may decrease. For example, a meat packer maintains a knowledgeable buyer at a market place with a large volume. The buyer has available the resources of the firm as well as his experience. With a declining volume, the cost per transaction of maintaining an experienced buyer at a particular location increases, and this buyer may be withdrawn. (Of course, other reasons may exist for the processor leaving the market.) Thus, the quality of information probably is reduced, and this poorer information may be translated into poorer price behavior. This argument does not necessarily suggest a bias in prices, but rather, larger errors in price formation.

Much of this paper deals with changes in prices with the passage of time and differences in prices among locations. The price discovery process is one of finding the warranted adjustments from existing levels as expectations about factors determining price change. Price changes are thought to follow a random walk or martingale process in a perfect market (Samuelson); but, for the purposes of this paper, the question is how may the number of transactions influence the discovery of warranted price changes? Intuitively, this number may not be a constant. An unexpectedly large change in supply, for example, may require more transactions to discover the correct change in price than does a small change in supply.

Defining a Thin Market

Chebyschev's inequality perhaps can help provide a specific definition of a thin market. One statement of the inequality (e.g., Cramer or Mood) is

$$P(|X_n - \mu| \geq c) \leq \frac{\sigma_n^2}{c^2},$$

where P defines the probability of the expression, and c is an arbitrary constant. X_n is a random variable with mean μ and variance σ_n^2. The subscript n is added to emphasize that X_n and σ_n^2 depend on n. For example, X might be an individual transaction price. Hence, X_n would be the mean of transactions prices for particular time period and σ_n^2 the variance of the distribution of the mean. One of the advantages of using Chebyschev's inequality is that it is applicable to distributions of random variables with finite variances. The results do not require that the distribution of prices or price differences be normal.[1]

In the inequality, μ can be treated as the true, but unknown, equilibrium price for given economic conditions (though this is not the definition used in most of the paper). Two views exist in the literature about the relationship of actual transactions prices X to the equilibrium μ. One is the $E(X) = \mu$; the mean of observed prices is treated as an unbiased estimate of the equilibrium. Some mixed evidence, based on experiments, exists about this assumption (Hess, Smith). In any case, the assumption implicit in most econometric models is that the average reported prices are equilibrium prices.

The tâtonnement process is a second concept for relating the X's to μ; prices progressively converge toward equilibrium (for a recent review, see Paul). Then, X_n is the last price in a series of n transactions and is the estimate of equilibrium. Again, one can ask, how many observations are needed to obtain a "precise" estimate of the population param-

[1] This paper does not discuss distributions of prices, but the topic is important for estimating the number of reported transactions needed for accurate pricing. Distributions of price differences on futures markets may not have finite variances (Mann and Heifner), but Samuelson hypothesizes that the variances of price differences on futures markets increase as the maturity of the futures approaches. In any case, this paper deals with changes in cash prices. Cash prices typically have been assumed to be distributed normally with constant variances. But the assumption of normality is based on an appeal to the Central Limit Theorem rather than on empirical analyses, and the analysis in the text suggests the variance is not constant. If the assumption of a normal distribution is accepted, then the probability of a particular level of precision could be greatly reduced relative to Chebyschev's inequality. For example, if $c = 2\sigma_n$, then by the inequality $P \leq .25$. For the normal distribution, $P \leq .05$. The use of Chebyschev's inequality can be justified as a conservative approach. On the other hand, the normal distribution is often assumed, and with estimated variances, the t distribution can be justified.

eter? A tâtonnement process, however, typically is not observable in real world data, and from a practical viewpoint, the average of transactions prices must be used.

Thus, defining a thin market is equivalent to finding the number of transactions, n, required to obtain a "large" probability that X_n is "close to" μ. To find n, Chebyschev's inequality may be rewritten as

$$P(-c \leq X_n - \mu \leq c) \geq 1 - \frac{\sigma^2}{nc^2}.$$

For the mean X_n to be within the range $-c$ to $+c$ to μ with probability P,

$$P = 1 - \frac{\sigma^2}{nc^2} \text{ or } n = \frac{\sigma^2}{(1-P)c^2}.$$

Alternatively, if an existing market or pricing arrangement has n transactions (per unit of time) with a particular variance, then the implied precision of pricing in terms of P and c can be estimated.

This framework suggests, first, that the definition of a thin market is somewhat arbitrary. It depends on the definitions of "large probability" and "close to," i.e., on c and P. A second implication is that the concept of a thin market is a relative one, given c and P fixed while σ varies. The number of transactions, n, will vary as σ varies if a fixed standard of precision is used.

From a sampling viewpoint, increasing n increases costs. From a price discovery viewpoint, the cost relation is less clear. Given N total transactions per day, n of them at a terminal market, thereby contributing to public information, little empirical research exists to explain why n is declining, although some obvious hypotheses exist. (It costs market participants less, say, to formula price based on a central market quotation than actually to participate on the central market.) Hence, a question arises about the trade-off between precise prices and the number of transactions, n. This is an area for fruitful research, but cost topics are not explored in this paper.

The discussion to this point has emphasized intraday or daily prices assuming fixed economic conditions. Obviously, with the passage of time, economic conditions and equilibrium prices change. Prices also vary, of course, with quality and space. In this context, the parameter μ can be interpreted as the true price difference (through time, between regions, or between qualities). The remainder of this paper uses, almost exclusively, price changes or differences. The unit of time also is important in defining a thin market. This paper considers day-to-day and week-to-week changes—the time periods usually considered in the thin market literature.

Measuring Performance

Measuring the performance of a thin market is a problem, in part, because the perfectly competitive norm is not observable. There are likely to be problems in developing a usable norm. Price differentials that should prevail under competitive conditions can be computed, and observed differentials can be compared with the computed values. For example, the differences in economic value of different yield grade carcasses can be computed based on the differences in saleable retail meat, and then actual price differences can be compared with the true economic differences (Trierweiler and Hassler).

Equilibrium price levels, of course, are not observable. In principle, an econometric model could be constructed and estimated. If the model were correct, it would provide unbiased estimates of equilibrium prices under stated conditions. However, most econometric models pertain to quarterly or annual observations and not to the daily or weekly prices of interest in thin markets. Moreover, it is always difficult to build correct models and especially difficult to model short-term prices. But, for short-term prices, the random walk model can be used as a norm (Mann and Heifner).

In this paper, prices on the Omaha market are used as a norm in the study of Denver prices. Omaha is, in effect, treated as a proxy for the national market. During the period under analysis, Omaha had a large volume of cattle sales, including choice steers, but of course no market is perfect. Imperfections are a matter of degree. Thus, while differences in performance may exist between markets, they may not be sufficiently large to be measurable by available data and statistical methods. On the other hand, if differences in price behavior are found, they could be due to factors other than differences in volume of trading. While such problems can not be solved, the Omaha market also was compared with the Sioux City market. The volume of choice steer sales remained reasonably large in Sioux City during

the sample period while the Denver market expired. Thus, Omaha prices can be compared with another large market and with a declining market place.

Data and Procedures

The Denver central market is potentially an interesting case study. In the mid-1950s, about 850 thousand cattle were marketed per year in Denver; well over 200 thousand were slaughter steers. By 1968, only 10 thousand steers were marketed, and in late 1968, volume was so light that price reports were sporadic. In November 1967, the market shifted to auction pricing of cattle, and the Agricultural Marketing Service discontinued price reporting for steers on the Denver market on 1 January 1969. It closed in 1972. While cattle marketings declined in all central markets especially after 1965, the volume in the late 1960s and early 1970s in Omaha and Sioux City was still greater than in Denver in the 1950s. Clearly the Denver market place became thin by any standard, while the volume in Omaha and Sioux City in the 1950s and 1960s seems adequate for price discovery purposes.

Prices were collected for choice, 1,100–1,300 pound steers at Omaha and Denver, for the 1955–68 period. The same prices were also obtained for Sioux City for selected years within this period. The range of prices on Monday of each week was recorded. Monday has had a large volume of slaughter steers relative to other days of the week. If Monday was a legal holiday, then Tuesday prices were used. Thus, each year has fifty-two or fifty-three observations, the number of Mondays per year.

The availability of prices only as a daily range raises questions about the comparability of the prices between markets. During the sample period, the instructions to market reporters were to give the range between good and prime steers based on market conditions for the day (not necessarily the range of actual transactions). Thus, the intent was for the midpoint of the price range to represent the midpoint of the range of quality of choice steers. The midpoint of the range is used in much of the analysis.

However, for thirteen of the fourteen years in the sample period, the range of daily prices in Omaha was on average wider than in Denver. The Omaha range was especially large during the early years, and it tended to narrow with the passage of time. This is a bit puzzling because market reporters in both locations had similar instructions. Literally interpreted, the data imply that the gap between good and prime steer prices was consistently larger in Omaha than in Denver. Another possible explanation is the difference in reporters' interpretations of the range of choice prices. Given that Denver had relatively few prime cattle, there also may have been few high choice steers causing the Denver reporter to focus upon a slightly lower grade than in Omaha. Some analysis was done using the low of the range on the assumption that these prices may be more comparable in the two markets. The low in Denver tended to decline relative to the low in Omaha. There is no clear trend in the differences of the midpoint, though this difference was quite large the last year of trading in Denver.

The data were plotted and evaluated visually; and the means, standard deviations, and coefficients of variation were computed by year and by month within years. The principal descriptive statistic presented is the coefficients of determination (r^2) for both price levels and first differences.

Regression models were also considered. The Denver and Omaha prices probably should be viewed as simultaneously determined; though, because Omaha is a much larger market, and because Denver is in a later time zone, causation each day may run more from Omaha to Denver than vice-versa. Because of transportation costs, prices in two locations can be somewhat independent of each other; Denver prices could move in a band about Omaha prices defined by transfer costs. Given these considerations, a simple model for the two markets is

$$(1) \qquad D_t = \Pi_0 + \Pi_1 M_t + \Pi_2 X_t + u_t$$

$$(2) \qquad M_t = \lambda_0 + \lambda_1 D_t + \lambda_2 Z_t + w_t,$$

where D is Denver price of choice steers on Monday; M, Omaha price of choice steers on Monday; t, Mondays (weeks); X, predetermined local conditions in Denver; and Z, predetermined local conditions in Omaha.

The problems of fitting equation (1) or (2) are the simultaneity of D and M and whether X and Z can be observed. Obvious candidates for X and Z are the receipts of choice steers in the respective markets on each Monday. Unfortunately these data are not available, though total receipts of cattle are. They were

not collected, however, when the price data were obtained.[2]

The Denver-Omaha price differences had a systematic pattern (were autocorrelated), and this probably is related to different patterns of marketings of steers in the two markets. Models that allowed for seasonality or trend were explored, and results for a first difference equation are presented.

$$(3) \quad D_t - D_{t-1} = \gamma + \beta(M_t - M_{t-1}) + v_t.$$

This equation was fitted by year and for selected pooled periods. The intercept can be viewed as a proxy for an omitted variable, and gamma is a measure of regional price differences used in the next section. Although the Durbin-Watson statistics were usually reasonable, equation (3) presumably is a misspecified version of equation (1), and likewise, while causation may run more from Omaha to Denver than the reverse, simultaneous equations bias probably is present in the least-squares estimates. Thus, the estimated parameters likely are biased, though alternative model specifications made little difference in the estimated slope coefficients. With these limitations in mind, emphasis is placed on descriptive statistics.

Empirical Results

An expression derived from Chebyschev's inequality is used to estimate whether or not Denver and Omaha might be considered thin markets. In

$$n = \frac{\sigma^2}{(1 - P)c^2},$$

P and c are selected rather arbitrarily. Emphasis is placed on obtaining an appropriate measure of the variance, σ^2, for the questions at hand. In this paper σ^2 estimated from Omaha prices is used for establishing n related to the change in the price level of choice steers. For Denver, the appropriate σ^2 relates to changes in price differences between Omaha and Denver.

Because the price level need not be rediscovered, a variance based on the first difference of prices is a sensible measure of the variability of the random variable in question. That is, μ for Omaha prices is defined as the change in true equilibrium prices, and σ^2 is estimated from the first differences of observed Monday prices by year.[3] This implies that week-to-week changes in the equilibrium are being analyzed. This variance overstates the difficulty of the market's problem because Omaha prices are available on more than one day per week.[4] In addition, as already discussed, the Chebyschev relation gives a fairly large n relative to assuming a precise distribution of price changes. On the other hand, σ^2 is estimated from market data and is not the true variance. Moreover, a variance based on Monday-to-Monday changes in the midpoint may understate the complexity of discovering the full range of prices from low to high choice steers. The values of n estimated should be treated as the approximations that they are.

For the computations, c was set equal to 10 (cents per hundredweight) and P to 0.9. The value of c is in the context of standard deviations of the first difference of Omaha prices that were often about 50¢ per hundredweight, though the range was from 21¢ to 69¢ for the years in the 1955–68 period. The values for c and P are also convenient in that $(1 - P)c^2 = 10$. Thus, the computed n is just the variance of the first differences of Omaha prices divided by ten. These values are shown in column one of table 1. In interpreting results, the reader should remember that they apply to discovering the price change for 1,100 to 1,300 pound choice steers and that the variance of Monday-to-Monday prices is based on a calendar year sample. In addition, the results are for a specific location, but they are "national" in the sense that they apply to changes in price level and not to changes in regional or quality differentials.

Because the first differences are from Monday to Monday, the estimated n may be inter-

[2] Available time and resources did not permit collection of the quantity observations subsequent to the collection of the price data. Moreover, the addition of seasonal dummy variables or the use of first differences had surprisingly little effect on the estimated slope coefficients, and the specification error bias may be small. Thus, the payoff to collecting market receipts data for total cattle marketings (another proxy variable) is unclear.

[3] The variance is computed from the Monday-to-Monday change in the midpoint of the range of prices. An alternative estimate of the variance could be obtained from the intraday range of individual prices. Assuming a symmetric distribution of prices within the range and given a typical range of $2 per cwt., the approximate standard deviation would be 48¢ per cwt. This value resembles the standard deviations computed from the first differences of midpoints.

[4] Steer prices were usually available on two or three days per week in Denver in the early and mid-part of the sample period, and this number declined to one per week and finally to zero per week. In any case, the collection of daily prices would have greatly increased cost of analysis. Hayenga suggested that one might study market thinness by analyzing prices on days with small volumes.

Table 1. Estimated Number of Transaction Prices for Choice Steers Required to Establish Accurate Price Changes

Year	Price Level Change	Denver-Omaha Difference
	(number per week)	
1955	277	61
1956	337	87
1957	176	70
1958	229	90
1959	193	37
1960	196	49
1961	133	44
1962	224	55
1963	262	65
1964	474	58
1965	243	32
1966	255	42
1967	94	34
1968	45	37

Note: See text for definition of accuracy.

preted as the number of prices (lots or transactions) required for establishing precise week-to-week price changes. The number is not directly comparable with saleable receipts because a typical lot would contain about twenty-five steers (though a lot size down to one is possible). To estimate an equivalent volume in terms of annual saleable receipts, the number of transactions is multiplied by twenty-five animals per lot and by fifty-two weeks. Thus, saleable receipts range from 58,500 in 1968, a year with small week-to-week price variability, to over 616,000 in 1964, a year of large price variability. These receipts are to maintain a precision of plus or minus 10¢ per hundredweight around the true change in mean prices with a 0.9 probability.

In the 1955–68 period, the saleable receipts of choice steers in Omaha ranged from 384 to 570 thousand, and these receipts typically were sufficient to meet the accuracy standard. They are clearly sufficient because the receipts in other markets also help determine the overall level of steer prices. For example, 991 thousand choice steers were sold in Omaha and Sioux City combined in 1964, the year with the largest "requirement" for transactions.

As stated earlier, steer prices are determined simultaneously, but for simplicity, the Omaha-Denver data are used to estimate the number of transactions required in Denver to discover precisely the change in the differential between Denver and Omaha. The differential in question is

$$\mu = (\mu_t^D - \mu_t^M) - (\mu_{t-1}^D - \mu_{t-1}^M),$$

where μ^D is equilibrium price in Denver, μ^M is equilibrium price in Omaha, and t, $t - 1$ is current and previous weeks.

To estimate n, the variance of $\hat{\mu}$ is needed. An estimated difference for a particular week is

$$\hat{\mu}_t = (D_t - M_t) - (D_{t-1} - M_{t-1}), \text{ or}$$
$$(D_t - D_{t-1}) = \hat{\mu}_t + (M_t - M_{t-1}).$$

For a year ($t = 1, \ldots, 52$), an estimate of an average μ and its variance can be obtained from the first difference equation (3), where the notation is changed so that $\gamma = \mu$. The parameter β is thought to equal one, though in practice it may not. In this paper, $\hat{\gamma}$ and its variance are obtained as least-squares estimates of (3).

The level of precision is defined as $P = 0.9$ and $c = 2$, and

$$n = \frac{\hat{\sigma}^2}{(0.10)(4)} = \frac{\hat{\sigma}^2}{.4},$$

where $\hat{\sigma}^2$ varies from year-to-year using equation (3). The level of c is set at a smaller level for the precision of the change in the regional differences than for the change in the price level, but the specific value 2 has no special justification.

The estimated values of n are given in column 2 of table 1, and n ranges from 32 in 1965 to 90 in 1958. As before, n can be interpreted as the number of transactions per week to establish precise changes in regional price differences from week to week. The equivalent annual saleable receipts range from 42 to 117 thousand choice steers. Although data are available only for total steer sales in Denver, receipts in the 1955–66 period appear adequate to discover precise price differences. In 1967 and 1968, however, about 48,000 head of steers would have been required each year for precise price discovery. In contrast, actual receipts were 28,000 and 10,000 steers of all qualities.

Chebyschev's inequality is not needed to demonstrate that the Denver market was thin in its last years, especially 1968. The application, however, does illustrate the complexity of the issue. Moreover, the results suggest that the price effects of a thin market, if any, are likely to be measurable only in 1967 and in 1968. In previous years, volume seemingly was adequate for fairly accurate pricing.

Price Behavior

This paper takes the position that the principal effect of the number of transactions is on the precision of pricing, and a number of measures of precision based on the weekly observations were explored. No simple relation was found between statistics like the range, standard deviation, or coefficient of variation of prices and market volume (e.g., table 2). The effect of volume was obvious in one respect: namely, weeks existed in late 1968 without reported prices for choice steers in Denver ($n = 0$).

The use of r^2, however, does suggest some imprecise price behavior associated with market volume. The coefficient of determination between Omaha and Denver prices was always above 0.81 (for weekly prices by year) from 1955 to 1967, but declined to 0.71 in 1968. For the first differences of prices, r^2 was usually above 0.5 in the 1955–66 period; r^2 for the first differences declined to 0.29 in 1967 and 0.04 in 1968 (table 3).

The first difference equation (3), as discussed, is of interest because the intercept coefficient provides a measure of the average change in regional differentials from week to week by year, and the model is also a way to take account of positive autocorrelation. The slope coefficients of equation (3) with Denver prices dependent tend to decline from the mid-1960s to the termination of the market. The first difference results are summarized by pooling the observations into two groups of years 1955–66 and 1967–68 (table 4). The average slope in the earlier period is 0.79 and in the final two years 0.46. Using the F-test for differences in models over time, the two equations are statistically different at the 5% level; however, given the heteroscedasticity apparent in the residuals of the individual year equations as well as other statistical problems, the hypothesis test should be taken with a grain of salt. Nevertheless, the results for equation (3) and for equations with seasonal dummies (not shown) clearly suggest a changing slope coefficient as market volume declined in Denver.

Table 2. Coefficients of Variation for Choice Steer Prices and Saleable Receipts of Slaughter Steers

	Coefficients of Variation[a]			Number of Steers		
Year	Denver	Omaha	Sioux City	Denver	Omaha	Sioux City
	-----	(%)	-----	---	(1,000 head)	---
1955	7.5	10.7	—[c]	221	864	462
1956	13.9	12.1	—	247	823	428
1957	8.3	7.5	—	192	768	461
1958	4.7	4.5	4.7	172	856	572
1959	3.1	5.1	4.9	169	896	617
1960	3.0	4.9	4.7	151	914	623
1961	5.4	5.7	5.8	163	921	677
1962	5.4	5.8	—	125	933	662
1963	5.6	5.8	—	127	923	639
1964	8.6	8.0	—	165	1,010	657
1965	6.4	6.1	—	104	884	550
1966	4.3	5.2	—	70	799	505
1967	4.3	4.4	4.4	28	704	492
1968	3.5[b]	3.1	2.4	10	586	468

[a] Computed from average price based on midpoint of Monday price ranges.
[b] Based on 43 observations.
[c] Sioux City prices not collected in all years.

Table 3. Coefficients of Determination for Steer Prices

	Price Level Omaha with		First Differences Omaha with	
Year	Denver	Sioux City	Denver	Sioux City
1955	.95	—	.53	—
1956	.96	—	.61	—
1957	.96	—	.20	—
1958	.82	.96	.56	.65
1959	.81	.97	.55	.51
1960	.87	.97	.31	.66
1961	.92	.98	.60	.73
1962	.91	—	.50	—
1963	.90	—	.62	—
1964	.96	—	.81	—
1965	.96	—	.70	—
1966	.91	—	.50	—
1967	.88	.98	.29	.57
1968[a]	.71	.96	.04	.53

[a] Denver observations available only for thirty-eight continuous weeks. Sioux City analysis uses same time period.

Table 4. First Difference Regressions for Pooled Years

Years	$\hat{\gamma}$	$\hat{\beta}$	r^2	d
1955–66	0.145 (1.402)[a]	0.794 (0.028)	0.562	2.49
1967–68	0.455 (2.657)	0.463 (0.097)	0.204	2.45

$F = 3.016$ (for hypothesis that regression parameters are equal in the two periods, numerator degrees of freedom = 2, denominator = 710).

Note: First difference of Denver prices dependent and first differences of Omaha prices independent variable (¢/cwt.)
[a] Standard error of coefficients in parentheses.

The foregoing evidence, of course, does not prove an association between performance and volume. One way to strengthen or weaken the case for the thinness of the Denver market is to compare Omaha prices with a market that still had a large volume in the sample period. Thus, choice steer prices in Sioux City were analyzed for the years 1958–61 and 1967–68, inclusive. These years were selected because they cover the range of results from the regression analysis of the Denver-Omaha relationship. Not surprisingly, the data show a close association between Omaha and Sioux City prices (tables 2 and 3). The correlations are near one, and the coefficients of variation are similar.

Perhaps the simplest way to compare the Denver and Sioux City markets is through the first difference regressions. The first differences of the midpoint prices for Sioux City are regressed against the first differences of Omaha prices (table 5), and these results can be compared with those for the Denver-Omaha equations. In the 1958–61 period, the Sioux City-Omaha and Denver-Omaha equations are qualitatively similar. In 1961, the hypothesis $\beta = 1$ cannot be rejected for both equations. In 1959 and 1960, the slope coefficients differ from one for both equations.[5] In 1958, the Sioux City equation has a slope different than one and the Denver equation does not, but the slope for the Sioux City equation, like Denver, has a magnitude greater than in 1959 or 1960. The r^2 coefficients are similar. In 1967 and 1968, however, the Sioux City-Omaha equations clearly differ from the Denver-Omaha equations in terms of slope coefficients and r^2's. These results strengthen the view that the precision of pricing in Denver was influenced by declining market volume.

The question of possible bias is more difficult to analyze, but the apparent differences in the seasonal pattern of marketings in the two regions (near Denver and Omaha) were used to explore the issue. In figure 1, the vertical axis is the difference between Omaha and Denver steer prices on average, by month, for the years 1961–65. These years were selected because the regression analyses suggested a close one-to-one relation between Omaha and Denver prices in this period after adjusting for seasonality. (The hypothesis that the true slope equalled one cannot be rejected in the regressions including seasonal dummies.) The horizontal axis of figure 1 measures regional differences in supply, which are approximated by using regional slaughter data for all cattle. Specifically, the sum of slaughter in the Mountain and Pacific regions is subtracted from the slaughter in the Northwest portion of the North Central region (includes Iowa and Nebraska). The dots in figure 1 are the average 1961–65 differences by month, and an inverse relation exists.

The exercise was repeated for the individual months October 1967 to September 1968, the last twelve months with complete weekly price data. This period is represented by the crosses in the figure. Obviously the relationship shifted to the right. For a given level of supply—a fixed difference in slaughter—Denver prices are lower relative to Omaha than in the earlier, base period. This is consistent with the possibility of the Denver market providing prices that are biased downward for given economic conditions. This may be related to the small volume in Denver, but an

Table 5. First Difference Equations, Denver and Sioux City, Selected Years

	Sioux City Price Dependent[a]			Denver Price Dependent		
Year	intercept	slope	r^2	intercept	slope	r^2
1958	−0.072	0.756	.65	0.200	1.021	.56
	(3.792)[b]	(0.079)		(6.008)	(0.127)	
1959	−0.900	0.605	.51	0.078	0.694	.55
	(3.649)	(0.084)		(3.856)	(0.088)	
1960	0.920	0.634	.66	−0.093	0.477	.31
	(2.821)	(0.064)		(4.434)	(0.101)	
1961	−0.526	0.938	.73	1.209	1.009	.60
	(2.883)	(0.080)		(4.218)	(0.117)	
·						
·						
·						
1967	1.180	0.818	.57	−0.292	0.548	.29
	(3.005)	(0.102)		(3.662)	(0.120)	
1968[c]	0.330	0.842	.53	2.599	0.216	.04
	(2.890)	(0.132)		(3.831)	(0.175)	

[a] Midpoint of choice steer prices on Mondays in cents per hundredweight. In each equation, the first difference of the Omaha price is the explanatory variable.
[b] Standard errors of coefficients in parentheses.
[c] Denver observations available only for thirty-eight continuous weeks. Sioux City equation uses same time period.

[5] Taken as a whole, all of the results indicate unusual price behavior in 1959 and 1960. In Sioux City-Omaha equations using price levels, the intercepts are two standard deviations above zero. In the first difference equations, the slopes differ from one. For the Denver-Omaha equations, the slopes are consistently below one. Since years before and after have the expected relationships, the performance in 1959 and 1960 is a puzzle. The answer to the puzzle is not within the scope of this paper.

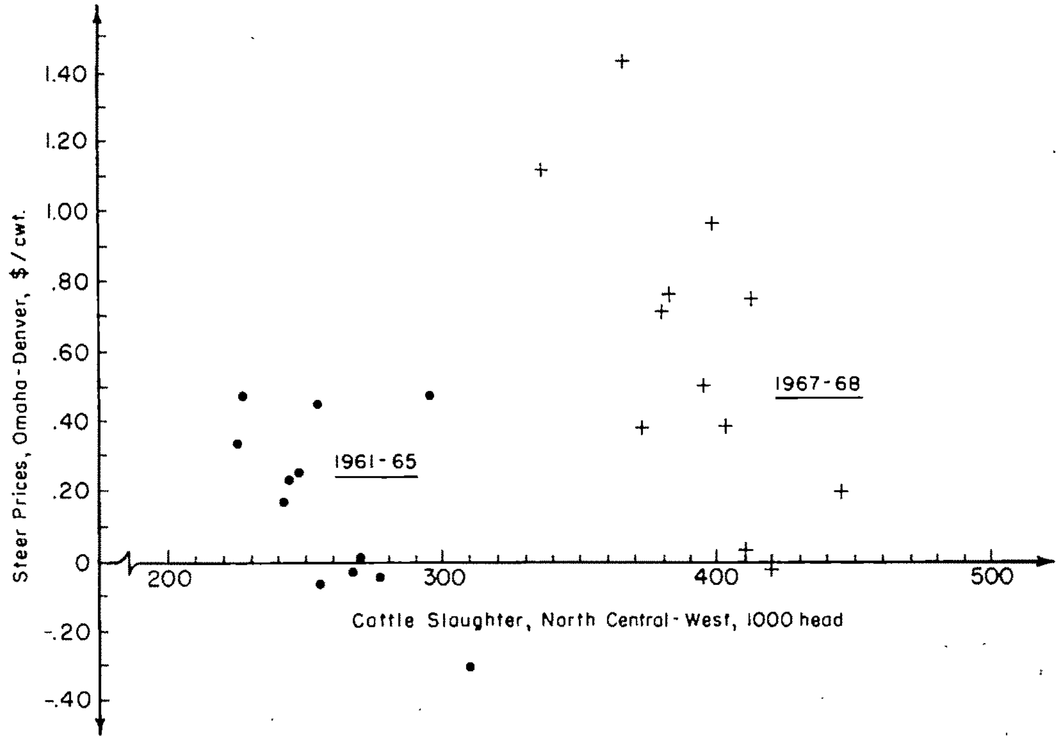

Figure 1. Regional differences in steer prices versus regional differences in cattle slaughter

exhaustive investigation of this hypothesis would require construction of a spatial equilibrium model, an analysis beyond the scope of this paper. Moreover, the regional supply variables used here are crude, and errors in measuring these variables may account for the shift.

Concluding Observations and Qualifications

This paper defines thinness by analogy with sampling concepts from statistics. This approach establishes a (perhaps arbitrary) standard of precision (price behavior), and then estimates the number of transactions required to obtain the standard. The approach has the advantage of defining what is meant by "precise" price behavior and of emphasizing the relative nature of defining a thin market. The structure of prices is exceedingly complex, however, and it may be difficult to estimate the number of transactions, n, required to avoid thinness. (An alternative application is to estimate the precision implied by existing volume, n.)

Given the complexity of establishing prices for live cattle, the number of transactions required to discover steer prices with considerable precision seems small to me. Apparently thirty to thirty-five transactions per Monday (about 50,000 steers per year) were adequate under the conditions of the 1960s to discover Denver prices rather precisely relative to the Omaha price. If a specific assumption were made about the distribution of price changes, the number would be even smaller.

The reader, however, should not be overly reassured by these results. Since the 1960s, commodity prices have become more variable. If a fixed standard of precision is maintained, such as 10¢ per hundredweight, then the number of public transactions must increase with the variance. In contrast, the trend has been toward declining volumes on central cash markets.

Estimates of the variance of changes in daily or weekly price from a sample of fifty-two weeks may be inappropriate for estimating n. The variance presumably should reflect changes in the current forces determining prices. If there is little reason for prices to change, then few transactions are needed to achieve a given level of pricing precision (and vice-versa). Thus, a sample based on a calendar year may not be from a population rele-

vant for estimating the variance needed for obtaining n. Intraday prices or a shorter period may be more appropriate (but see note 4). Also, prices varied little in the 1955–68 period relative to the 1970s, and even for the period studied, the variances of weekly prices by years were unstable. The question of an appropriate sample period for estimating a relevant σ^2 is not fully answered in this paper.

In interpreting the results, the distinction between a market and a market place or a market channel must be kept in mind. Denver was just one market place in a national cattle market. Thinness in Denver does not, of course, necessarily imply thinness in the market in general. But, to the extent publicly reported prices are needed to establish regional or quality differentials, a problem of thin markets may remain. The Denver market place became a poor place to discover regional prices for choice steers relative to the Omaha market place. Because, during the period studied, fed cattle production was growing in Colorado, regional price differences were probably better established in a market channel other than the Denver terminal market, but it may be more costly to obtain public price reports from channels other than central markets. If the principal role of publicly reported prices is to establish a known, national base for other transactions, then the increased volume of trading on futures markets may assist in establishing an accurate base (Cox).

Another issue is whether the items priced on the central market are representative of the full population of items being sold. It is alleged, for example, that the lots sold on central markets tend to be lower quality than the typical lots of the product. The observed prices may not be a random sample of the population prices. For pricing, however, a random sample may be unnecessary. If the items priced on a central market are of a known quality, then the price established for that quality can be used to price other quality products. The remaining prices need only establish the correct difference. Thus, bias is permitted if a correction factor can be obtained, but the assumption $E(X) = \mu$ rules out the use of manipulated prices in estimating the true equilibrium.

With respect to performance of prices on a terminal market, thinness can mean that no transactions occur over extended periods of time. Consequently, the descriptive statistics, such as the mean and variance, become more difficult to interpret. For the period with continuous price series, r^2 between Omaha and Denver prices declined, and the slope coefficient moved further from one. From a technical statistical viewpoint, this does not necessarily mean prices are biased; rather one may say that prices are established with less precision as volume declines. Individual prices and their averages have larger errors, but these errors can be offsetting so that, on average, there is no bias.

In evaluating the results, it is not appropriate to talk in terms of formal hypothesis tests. A given data set was subjected to many exploratory analyses, thereby reducing levels of significance (Wallace). Nonetheless, the results are clearly compatible with the hypothesis that declining volume results in imprecise pricing. This is the implication of the analysis of Denver prices, strengthened by the Sioux City results. Moreover, logic alone suggests that declining information will result in larger pricing errors.

Given the historical nature of the analysis, the empirical results are not immediately applicable to a current problem, but the results do seem to point toward useful methods of studying thin markets.[6] It may be possible to estimate the number of transactions required for a given level of pricing precision or to estimate the precision implied by the existing volume. Such estimates can be sharpened over those of this paper, if convincing evidence is provided that price changes have a specific probability distribution and if an appropriate sample can be ascertained for estimating σ^2. Other research needs to consider the costs of improving pricing precision and to suggest less arbitrary ways of defining the precision parameter, c. For example, the concept of price risk might enter into defining c. Many of the problems of analysis found in this paper seem surmountable, and analyses of current issues, such as the pricing of beef carcasses, could be attempted.

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[6] Several reviewers have suggested that the sampling analogy gives a misleading definition of a thin market. For example, the mere use of number of transactions misses the possibility that one transaction may contain more information than another; all transactions are not equal in the amount or quality of information provided. But such an objection might be overcome by extending the results of this article to include stratified sampling, or if nothing else, particular markets might be analyzed in terms of their ability to provide judgment samples. In the author's view, it is important to develop a concept of a thin market that has empirical content. The sampling framework is one approach to empirical analysis, and hopefully readers will be motivated to make extensions and improvements.

References

Cox, Charles C. "Futures Trading and Marketing Information." *J. Polit. Econ.* 84(1976):1215–37.

Cramér, Harald. *Mathematical Methods of Statistics.* Princeton, N.J.: Princeton University Press, 1946.

Hayenga, Marvin L., ed. *Pricing Problems in Food Industry (with Emphasis on Thin Markets).* North Central Project 117, Monograph 7, 1979.

Hess, Alan C. "Experimental Evidence on Price Formation in Competitive Markets." *J. Polit. Econ.* 80(1972):375–85.

Mann, Jitendar S., and Richard G. Heifner. *The Distribution of Short-Run Commodity Price Movements.* USDA Tech. Bull. 1536, Mar. 1976.

Mood, A. M. *Introduction to the Theory of Statistics.* New York: McGraw-Hill Book Co., 1950.

Paul, Allen B. "Some Basic Problems of Research into Competition in Agricultural Markets." *Amer. J. Agr. Econ.* 61(1979):170–7.

Samuelson, Paul A. "Proof that Properly Anticipated Prices Fluctuate Randomly." *Ind. Manage. Rev.* 6(1965):41–9.

Smith, Vernon L. "An Experimental Study of Competitive Market Behavior." *J. Polit. Econ.* 70(1962):111–37.

Trierweiler, John E., and James B. Hassler. "Measuring Efficiency in the Beef-Pork Sector by Price Analysis." *Agr. Econ. Res.* 23(1971):11–17.

Wallace, T. Dudley. "Pretest Estimation in Regression: A Survey." *Amer. J. Agr. Econ.* 59(1977):431–43.

The Impact of Component Pricing of Soybeans and Milk

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Currently, the price that an individual farmer receives for soybeans is not adjusted for oil and protein content, and the price for milk is adjusted for fat content but not for solids-not-fat. This study finds that the potential social surplus gains from a change to component pricing of these commodities is small (no more than one to two percent of current commodity value, before deducting the extra costs of such a pricing system). Substantial transfers would occur between component-consuming groups, while producers as a group would be affected only slightly.

Key words: component pricing, milk market, soybean market.

It is in the nature of many commodities, particularly agricultural commodities, that quality varies from batch to batch. Where the dimensions of quality are easily discernable, market prices presumably will vary from batch to batch to reflect quality differences; but where information about product quality is expensive to obtain, market participants may be willing to transfer a commodity batch with very little information about the quality of that particular batch. In the latter case the market prices may only weakly transmit to the producer the consumers' preferences for various aspects of product quality, which in turn suggests that social welfare gains could be achieved if information about the quality of each batch could be obtained at sufficiently low cost. The purpose of this paper is, first, to show how an increase in the accuracy of price transmission would affect equilibrium prices, quantities, and social surplus in the markets for a commodity for which value is determined by the amount of and market prices for the components contained in a particular batch. The market for such a commodity is somewhat simpler than those generally considered by the literature on hedonic prices, where product quality dimensions are not decomposed and priced separately, as they are here. The second objective of the paper is to estimate the size of the potential equilibrium displacements which would occur in the markets for soybeans and milk, if these commodities were priced on the basis of perfect information about the components contained in each batch traded. The interest in these two commodities arises from the introduction in recent years of electronic scanning devices which may substantially lower the cost of obtaining information about component content.

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The Economic Model

The market to be analyzed is that of a commodity whose market value derives solely from two components in the commodity, call them component A and component B. The objective is to compare the market equilibria which would exist under two pricing institutions. The first I will refer to as "commodity pricing," in which the price per unit of the commodity is not adjusted to reflect component content. The second I will refer to as "component pricing," in which the commodity is exchanged on the basis of the value of components A and B in the commodity batch being exchanged.

The two market equilibria are illustrated in figure 1. The production possibilities curve is labeled PPC. Producer equilibrium is determined by the ratio of implicit prices which they receive for the two components, designated as w_a and w_b. First consider the condi-

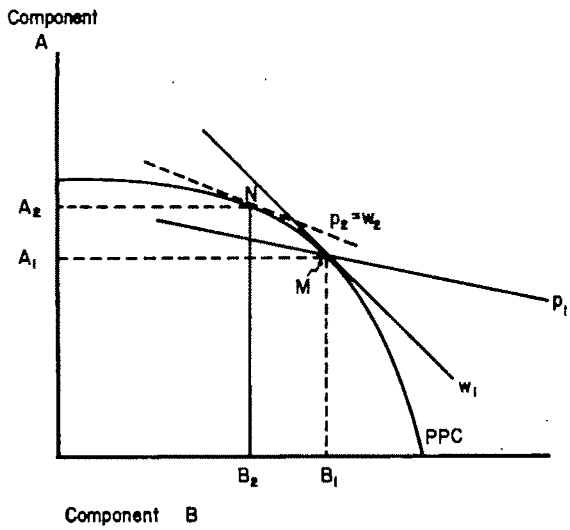

Figure 1. Commodity pricing and component pricing equilibria

tions for equilibrium under commodity pricing. Producers are paid the commodity price for their product, regardless of component composition. Therefore, the ratio of implicit component prices, w_a/w_b, is equal to 1.0, and the slope of the iso-revenue line (w_1 in figure 1) is -1.0. Point M therefore indicates the equilibrium levels of component production, A_1 and B_1, under commodity pricing. The component prices for this equilibrium, p_a and p_b likely will exhibit a ratio different from 1.0, because those prices are determined by consumer demand in the component markets, given the levels of production A_1 and B_1. Thus, under commodity pricing a wedge separates the two price ratios p_a/p_b and w_a/w_b. Now, if component pricing were implemented, a new equilibrium would occur at some point such as point N, where the component price ratio and the implicit producer price ratio are equal to each other and to the marginal rate of transformation between A and B. Compared to the equilibrium M, the component pricing equilibrium N will result in more production of A, the higher priced of the two components, and the component price ratio p_a/p_b will have fallen to a level below its original level but still greater than 1.0, the original ratio w_a/w_b.

A relevant question is why commodity pricing could occur as an equilibrium in a competitive market, given the incentives for arbitrage implied by the divergence of the price ratios w_a/w_b and p_a/p_b. A plausible explanation is that the screening and transactions costs necessary to monitor the component content of each commodity batch sold may exceed the potential arbitrage returns. If this is the case, the commodity pricing equilibrium is socially as well as privately optimal, despite the price transmission wedge. Improved technology eventually may reduce these screening and transactions costs sufficiently to induce a change to component pricing. While it would be useful to pursue an analysis of the equilibrium level of information about commodity quality (as in Kihlstrom, for example), such an analysis is beyond the scope of this paper. For this paper, the more limited objective is to analyze the potential effects on producers and consumers should component pricing be costlessly implemented.

Next, the impact of component pricing versus commodity pricing is analyzed in greater detail with a more complete specification of the market. First we specify that components A and B are produced jointly, using a vector of inputs Z, and that the production function $\phi(A, B, Z)$ is groupwise additive in outputs and inputs, that is, $Q(A,B) = G(Z)$, where $Q(A,B)$ represents transformation between components, and $G(Z)$ represents substitution among inputs (see Christensen, Jorgenson, Lau, p. 31). By suitable scaling, Q and G may be measured in units of the commodity. The function $Q(A,B)$ is assumed homogenous of degree one in A and B.[1] The nature of the function G is of no particular interest in component pricing analysis, except to note that a fixed level of inputs Z gives rise to a production possibilities frontier that is fixed, such as the one in figure 1. Supply conditions in the Z markets, however, give rise to a supply curve for the commodity, $f(p)$, permitting the production possibilities curve to shift in and out.

A complete set of equations describing the industry equilibrium is as follows:[2]

(1) $Q = f(p)$,

(2) $Q = Q(A,B)$,

(3) $w_a = pQ_A$,

(4) $w_b = pQ_B$,

(5) $A = p_a(A)$,

(6) $B = p_b(B)$,

[1] While the assumptions of additivity and homogeneity are plausible over a limited range of the production function, they certainly would be questionable over very wide ranges, as pointed out by a reviewer.

[2] This formulation and the subsequent analysis was suggested by the approach of Muth.

(7) $\gamma = (p_aA + p_bB)/w_aA + w_bB),$

(8) $\rho = (w_a/w_b)/(p_a/p_b).$

The first equation specifies the supply of the commodity, the second is the production function, while the third and fourth specify producer equilibrium in the production of components A and B (given the implicit prices they face, the supply price of the commodity itself, and the partial derivatives of the transformation function, Q_A and Q_B.) Equations (5) and (6) specify equilibrium in the consumer markets, given the demand curves $p_a(A)$ and $p_b(B)$. The seventh equation describes what can be generally interpreted as the percentage processing margin—the ratio of the value of the components sold in the component markets to the value received by producers.[3] Equation (8) is an identity which defines the size of the price wedge between producers' and consumers' markets. Under component pricing it is assumed that no wedge exists, so that $\rho = 1$. Under commodity pricing, ρ may take on any positive value.

We now proceed to establish the effect on equilibrium prices and quantities of an exogenous change in ρ from its equilibrium level under commodity pricing to 1.0, the equilibrium level which would exist under component pricing. Displacements from equilibrium can be expressed conveniently in terms of percentage changes in the variables, designated here with the operator E, *i.e.*, $EA = dA/A = d\ln(A)$. Total differentiation of equations 1, 5, and 6 yields:

$$(1') \qquad \frac{1}{e} EQ - Ep = 0,$$

$$(5') \qquad \frac{1}{n_a} EA - Ep_a = 0,$$

$$(6') \qquad \frac{1}{n_b} EB - Ep_b = 0,$$

where e is the elasticity of supply of the commodity and n_a and n_b are elasticities of demand for component A and component B. The differentiated form of equation (7) can be expressed conveniently in terms of component shares, where k_a and k_b are the component shares $k_a = w_aA/(w_aA + w_bB)$, $k_b = w_bB/(w_aA + w_bB)$, and s_a and s_b are component shares $s_a = p_aA/(p_aA + p_bB)$, $s_b = p_bB/(p_aA + p_bB)$. Then given the identity

$$(9) \qquad E(w_aA + w_bB) = \frac{1}{w_aA + w_bB} \{w_aAEA + Aw_aEw_a + w_bBEB + Bw_bEw_b\},$$

and assuming for ease of analysis that the processing margin is constant ($E\gamma = 0$), the differentiated form of (7) may be expressed as

$$(7') \qquad (k_a - s_a)EA + (k_b - s_b)EB + k_aEw_a + k_bEw_b - s_aEp_a - s_bEp_b = 0.$$

Differentiation of (8) is direct and yields

$$(8') \qquad Ew_a - Ew_b - Ep_a + Ep_b = E\rho.$$

To express the differentiation of equations (2) and (3) conveniently, it is useful to draw upon three properties of functions, such as $Q(A,B)$ which are homogeneous of degree one:

property (a): $AQ_A + BQ_B = Q,$

property (b): $Q_{AA} = -\frac{B}{A}Q_{AB},$

property (c): $\tau \equiv \dfrac{E\left(\frac{A}{B}\right)}{E\left(\frac{dA}{dB}\right)} = \dfrac{Q_AQ_B}{QQ_{AB}},$

where τ is by definition the elasticity of transformation and is negative for convex production frontiers.

By definition:

$$(10) \qquad EQ(A, B) \equiv \frac{1}{Q} (Q_AAEA + Q_BBEB).$$

Then from property (a) and the equilibrium conditions (3) and (4),

$$(11) \qquad EQ(A, B) = k_aEA + k_bEB,$$

and therefore the differentiated form of (2) can be expressed as

$$(2') \qquad EQ - k_aEA - k_bEB = 0.$$

Finally, note that by definition,

$$(12) \qquad EQ_A \equiv \frac{1}{Q_A} (Q_{AA}AEA + Q_{AB}BEB).$$

Invoking properties (b) and (c), this may be expressed as

$$(13) \qquad EQ_A = \frac{k_b}{\tau} (-EA + EB),$$

[3] Equations (3) and (4), along with the homogeneity condition $AQ_AA + Q_BB = Q$ insure that implicit producer receipts $(w_aA = w_bB)$ equal commodity receipts (pQ).

so that the differentiated forms of equations (3) and (4) are

$$(3') \quad Ew_a - Ep + \frac{k_b}{\tau} EA - \frac{k_b}{\tau} EB = 0,$$

$$(4') \quad Ew_b - Ep - \frac{k_a}{\tau} EA + \frac{k_a}{\tau} EB = 0.$$

The set of eight equations (1′)–(8′) describes the equilibrium displacement of the eight endogenous variables $(Q, p, A, B, w_a, w_b, p_a, p_b)$. The only exogenous disturbance considered here is the change in ρ. The solution to the system can be obtained by row operations on the matrix to define two new equations, eliminating EQ, Ep, and the four component prices.[4] These two equations in EA and EB can be solved easily using Cramer's rule. Given the solutions for EA and EB, the solutions for the other variables are determined easily from the original equations. Below are the resulting elasticities of equilibrium prices and quantities with respect to changes in ρ, and the sign of these elasticities as derived in the following paragraph.

$$(15) \quad EA = -\frac{1}{D}\left[k_b\left(1 + \frac{1}{e}\right) - s_b\left(1 + \frac{1}{n_b}\right)\right]E\rho \geq 0,$$

$$(16) \quad EB = \frac{1}{D}\left[k_a\left(1 + \frac{1}{e}\right) - s_a\left(1 + \frac{1}{n_a}\right)\right]E\rho \leq 0,$$

$$(17) \quad Ew_a = \frac{1}{D}\frac{k_b}{\tau}\left(\frac{1}{e} - \frac{s_b}{n_b} - \frac{s_a}{n_a}\right)E\rho \geq 0,$$

$$(18) \quad Ew_b = -\frac{1}{D}\frac{k_a}{\tau}\left(\frac{1}{e} - \frac{s_b}{n_b} - \frac{s_a}{n_a}\right)E\rho \leq 0,$$

$$(19) \quad EQ = \frac{1}{D}\left[k_a s_b\left(1 + \frac{1}{n_b}\right) - k_b s_a\left(1 + \frac{1}{n_a}\right)\right]E\rho,$$

$$(20) \quad Ep = \frac{1}{D}\frac{1}{e}\left[k_a s_b\left(1 + \frac{1}{n_b}\right) - k_b s_a\left(1 + \frac{1}{n_a}\right)\right]E\rho, \text{ where}$$

$$D = \frac{1}{\tau}\left[\frac{1}{e} - \frac{s_a}{n_a} - \frac{s_b}{n_b}\right] + \frac{1}{n_b}\left[k_a\left(1 + \frac{1}{e}\right) - s_a\left(1 + \frac{1}{n_a}\right)\right] + \frac{1}{n_a}\left[k_b\left(1 + \frac{1}{e}\right) - s_b\left(1 + \frac{1}{n_b}\right)\right] \leq 0.$$

The indicated signs of these elasticities are reasoned as follows. For agricultural commodities, it will be true generally that the elasticities of demand for A and B are between zero and -1. Elasticity of supply e is positive as are all component shares, and τ is negative. From these assumptions, D is negative. To establish signs on the variables, arbitrarily designate A as the component with higher price under commodity pricing, as was illustrated in figure 1. Then, considering a displacement from the commodity pricing equilibrium M to the component pricing equilibrium N, ρ will increase from a value less than one to a value of one. Under these conditions, the signs of (15)–(18) are unambiguously established. The signs of EQ and Ep are identical, but are not determined a priori. Equilibrium commodity output will increase, however, if the elasticity of demand for A is sufficiently large relative to that for B.

The market problem in figure 1 is a special case of the problem just described, the case of $e = 0$, for which the production possibilities curve is fixed. Factoring $1/e$ from numerators and denominators and canceling, equations (15)–(20) yield the following when evaluated for the special case of $e = 0$:

$$(15') \quad EA = -\frac{k_b}{D_1}E\rho,$$

$$(16') \quad EB = \frac{k_a}{D_1}E\rho,$$

$$(17') \quad Ew_a = \frac{1}{\tau}\frac{k_b}{D_1}E\rho,$$

$$(18') \quad Ew_b = -\frac{1}{\tau}\frac{k_a}{D_1}E\rho,$$

[4] Specifically, define one new equation as the following combination of the original eight: (1′) + (1/e)(2′) − (k_a)(3′) − (k_b)(4′) − (s_a)(5′) + (s_b)(6′) + (s_b)(6′) + (7′). Define the second new equation as −(3′) + (4′) − (5′) + (6′) + (8′).

(19′) $$EQ = 0,$$

(20′) $$Ep = \frac{1}{D_1}\left[k_a s_b\left(1 + \frac{1}{n_b}\right) - k_b s_a\left(1 + \frac{1}{n_a}\right)\right]E\rho, \text{ where}$$

$$D_1 = \frac{1}{\tau} + \frac{k_a}{n_b} + \frac{k_b}{n_a}.$$

It is interesting to note the effect of the three elasticity parameters, τ, n_a and n_b, in this case. The smaller are these elasticities (in absolute value), the smaller will be the displacement of equilibrium M to equilibrium N in figure 1. As any one of these elasticities approaches zero, points M and N converge to the same point, and there will be no social gain from component pricing. This is intuitively reasonable, because if τ is zero, there is no production opportunity for changing the ratio of components in response to the new market signals. If either demand elasticity is zero, there is no willingness by consumers to accept other combinations of components. Hence, a highly elastic transformation curve alone is not a sufficient condition for changes in component ratios in response to component pricing.

The final analytical step is to determine the effect of the equilibrium displacement on producers, on consumers of commodity A, and on consumers of commodity B. Willig has shown that for most practical purposes, the area under the demand curve and above the price line serves as a precise measurement of the amount of income change which would be required to compensate consumers for a movement along the demand curve. If the demand elasticities are constant over the range of this movement, then this measure of consumer surplus change for a good is

(21) $$\Delta CS = \int_{p_2}^{p_1} \alpha p^n dp = \frac{\alpha}{1 + n} p_1^{1+n}[1 - (1 + Ep)^{1+n}],$$

where α is an arbitrary constant and n is demand elasticity. Expressed as a fraction of the original value of the good, the change in consumer surplus is

(22) $$\frac{\Delta CS}{p_1 X_1} = \frac{1}{1 + n}[1 - (1 + Ep)^{1+n}],$$

which is positive for price decreases and negative for price increases. Similarly, the change in producer surplus as a fraction of the original value of a commodity can be represented as

(23) $$\frac{\Delta PS}{p_1 q_1} = \frac{1}{1 + e}[(1 + Ep)^{1+e} - 1],$$

which is positive for price increases and negative for price decreases. In the case of $e = 0$, the change in producer surplus as a fraction of commodity value reduces simply to Ep.

The model described above provides a method of evaluating the potential gains and losses to consumer and producer groups from a movement toward component pricing—that is, a movement toward equality of component price ratios in consumer and producer markets. (Solutions to the model will not provide exact equilibrating market conditions, because the equilibrium displacements are evaluated at initial market shares.) The cost of implementing component pricing is not considered explicitly, though this consideration could be accommodated easily by specifying a simultaneous exogenous shift of the appropriate size in the processing margin, designated in the model as γ. A more serious deficiency of the model is that it does not address the question of the market equilibrium level of information about the component quality of commodity batches being traded. Thus, it provides no insights as to when component pricing will occur. Despite this limitation, the model is useful in evaluating the potential impacts of a change from existing levels of price wedges to a perfectly implemented component pricing structure.

Component Pricing of Soybeans

The model just presented was developed to examine the potential impact of a change in market information technology for agricultural products. New instruments utilizing near-infrared reflectance and nuclear magnetic resonance hold some promise as methods of providing quick, inexpensive, and accurate information about the protein and oil content of milk and soybeans at the point of first sale (see Niernberger, and Updaw and Nichols). The soybean market is particularly amenable to the component pricing model because soybeans are used almost exclusively for processing into soybean oil and soybean meal, and there are well-defined market prices for each of these

components. Under the current pricing system, each individual farmer sells soybeans to processors or country elevators on the basis of weight, generally adjusted only for moisture content. While it is likely that prices paid to all farmers are adjusted for differences in the average component content between producing areas or between crop years, prices paid to individual farmers are not adjusted to reflect the component content of his lot of grain. In effect, then, producers face a 1:1 price ratio for the oil and protein that are produced and sold with the soybeans.

The elasticities of demand for soybean oil and meal have been studied by several authors. The elasticity estimates for oil have not been very consistent, ranging from −4 (Brandow) to −0.3 (Houck, Ryan, Subotnik). Protein meal elasticity estimates have been only a little more consistent, ranging from −0.9 (Houck) to −.14 (Houck, Ryan, Subotnik). For this initial approximation of the impact of component pricing, demand elasticities are assumed to be −0.5 for both components. Soybean supply elasticity is estimated alternatively at 0 and 1.5. (A recent study by Gardner estimates the long-run supply elasticity for soybeans to be about 1.3.) Estimates of the elasticity of transformation between protein and oil production are not at present available though efforts are underway (Updaw). For this analysis, alternative elasticities of −0.5 and −1.5 will be examined. Of course, if the transformation elasticity is zero, there would be no change in quantities or consumer prices, but implicit producer prices would change.

The commodity pricing equilibrium taken as a point of departure is the simple average of annual prices and quantities during the four crop years beginning September 1974. These values, shown in table 1, indicate that the ratio of oil price to protein price in the component markets has been about 1.33. The implicit farm price of the components is taken to be the farm value of soybeans divided by the total pounds of oil and protein, or \$.19/lb. The value of ρ, the price wedge, is then 1.0/1.33 = 0.75, so the percentage change in ρ, which corresponds to a shift to perfect component pricing, is .25/.75 = .33. At the initial prices and quantities shown, oil represented a share s_a of .41 in the value of components derived from soybeans, but an implicit share k_a of only .34 in the farm value of soybeans since that is its share of component weight and the two components are implicitly priced equally.

The equilibrium displacements from a shift to component pricing are shown in table 2 in percentage terms and in table 1 in equilibrium quantities and prices. Oil production would increase by up to 8% and protein production would fall by up to 5%, depending on the elasticities assumed. Price changes are greater, due to the inelasticity of demands. These are

Table 1. Commodity Pricing and Component Pricing Equilibrium in the Soybean Market

Endogenous Variable	Symbol	Commodity Pricing Equilibrium	Component Pricing Equilibrium $e = 0$, $\tau = -.5$	$e = 1.5$, $\tau = -.5$	$e = 1.5$, $\tau = -1.5$
Soybean production (billion lb.)	Q	87.12	87.12	86.94	86.85
Oil production (billion lb.)	A	15.84	16.70	16.67	17.08
Protein production (billion lb.)	B	30.43	29.57	29.51	29.05
Farm price of soybeans (\$/lb.)	p	.101	.1004	.1009	.1008
Price of oil (\$/lb.)	p_a	.243	.2166	.2176	.2049
Price of protein (\$/lb.)	p_b	.183	.1933	.1940	.2000
Farm price of oil (\$/lb.)	w_a	.190	.2106	.2106	.2003
Farm price of protein (\$/lb.)	w_b	.190	.1793	.1793	.1846
Farm value of soybeans (\$ billion)		8.800	8.751	8.772	8.754
Value of components (\$ billion)		9.418	9.334	9.355	9.310
Change in:					
Producer surplus (\$ billion)			−.048	−.005	−.008
Oil consumer surplus (\$ billion)			.430	.413	.628
Protein consumer surplus (\$ billion)			−.310	−.333	−.495
Net social surplus (\$ billion)			.072	.075	.125

Sources: USDA, *Fats and oils situation,* various issues. Oil and protein production are calculated from total soybean production and the yields of oil and 44% protein meal for those soybeans crushed domestically. Oil price is for oil in tank cars at midwest mills. Protein price is calculated from the price of 44% protein meal at Decatur. Initial farm price for oil and meal is calculated as the total value of soybeans at the farm price, divided by the sum of oil and protein production.

Table 2. Percentage Equilibrium Displacement from Component Pricing of Soybeans

Endogenous Variable	Symbol	Displacement of Equilibrium Values from Component Pricing		
		$e = 0$ $\tau = -.5$	$e = 1.5$ $\tau = -.5$	$e = 1.5$ $\tau = -1.5$
		(%)		
Soybean production	Q	0	−0.21	−.31
Oil production	A	5.43	5.22	7.83
Protein production	B	−2.82	−3.03	−4.54
Farm price of soybeans	p	−0.55	−0.14	−0.21
Price of oil	p_a	−10.86	−10.44	−15.66
Price of protein	p_b	5.64	6.06	9.08
Farm price of oil	w_a	10.86	10.86	5.42
Farm price of protein	w_b	−5.64	−5.64	−2.82
Change in social surplus as a percent of value:				
Producer surplus		−0.55	−0.06	−0.09
Oil consumer surplus		11.17	10.73	16.33
Protein consumer surplus		−5.56	−5.97	−8.88
Net social surplus		0.8	0.8	1.4

rather substantial changes, and in terms of consumer surplus amount to gains to oil consumers of up to $628 million and losses to protein consumers of up to $495 million. If oil consumers actually compensated protein consumers for their losses, consumers as a group would be better off under component pricing, but without such compensation there is no basis in economic theory for deciding whether oil consumers are unfairly subsidizing protein consumers under the present pricing structure, or whether protein consumers would be unfairly penalized by the shift to component pricing. If the two groups were essentially the same persons, this equity question would be of less concern, but this is not entirely the case because oil is destined to consumers in the form of vegetable oils and shortenings, while protein is for the most part destined to consumers after being converted into meat by the livestock industry.

Ignoring this equity issue, the potential net efficiency gains (including the minor impact on producers) are small, at most about $125 million, or about 1.4% of the value of the annual soybean crop. It seems plausible that this is a sufficient gain to offset the additional costs of instruments and sampling efforts to implement component pricing, because the entire soybean marketing and processing margin is now only about 7% of the crop value. But if the elasticity of transformation is substantially less than −1.5, the net gains may be insufficient to offset the additional costs of component pricing. While this study does not address the question of whether component pricing would become the market-determined pricing structure, it is at least plausible that firms' incentives to price by components could lead to component pricing even if market efficiency were reduced. This corresponds to the possibility of socially excessive equilibrium levels of information suggested in other contexts by Hirshleifer and by Spence.

Component Pricing of Milk

Most milk marketed in the United States is priced on the basis of a base price for milk with 3.5% fat content, plus a premium or discount for each tenth of a percent deviation from this level. In some European countries and in a few marketing areas in the U.S., notably California, price is based on the content of protein or on solids-not-fat (SNF) as well as fat content. The past decade has seen a continued discussion of possible multiple-pricing schemes for the entire United States and their effects on different groups of producers and consumers (see Ontario Milk Marketing Board, and Smith and Snyder). Those who have favored multiple component pricing have argued that it is equitable to pay farmers on the basis of the value of the components that they produce, and that marketing efficiency is improved when producer prices more accurately reflect the preferences of consumers. None of the studies has attempted to evaluate the dollar equivalent of such efficiency improvements.

One reason for the lack of a definitive analysis of milk component pricing is that the various components (fat, protein, lactose, water, etc.) are not exclusively extracted and sold separately. While markets exist for some of the components, they are for the most part sold in products such as whole milk, ice cream, cheese, butter, etc., in which the components are not necessarily identified but do contribute to product quality. Therefore, the market value of every component is not readily observable, and a consumer goods characteristics demand approach (see Ladd) would be useful in establishing implicit consumer values for the various components. The California pricing system, however, is based on just three components, fat, solids-not-fat, and fluids, with the prices for the first two based on support prices for butter and for nonfat dry milk as announced by the U.S. Department of Agriculture, and the value of fluids determined as a residual (Ontario Milk Marketing Board, p. 37). The following analysis examines the potential impact of a similar two-component-pricing plan if it were introduced into areas currently under federal milk marketing orders, which currently account for about 60% of all U.S. milk production.

The average annual production of milk, butterfat, and SNF during 1974–76 in the federal order milk markets is shown in table 3. The implicit component prices faced by farmers are not obvious under the current fat-based pricing system. They were approximated for this study as follows. The average base price for 3.5% butterfat milk during this period was \$.0852/1b. The average fat content of all milk actually sold was 3.67% butterfat, and the average price paid for this milk was \$.0867. This implies that the average premium for extra butterfat was \$.882/1b. If the remaining value of milk during this period is imputed to SNF produced, then the price per pound of SNF was \$.630, so that $w_a/w_b = .882/.63 = 1.4$. In the component markets, the average price paid for butterfat in cream was reported as \$.77/1b., and the average price for nonfat dry milk was \$.61, giving the ratio of $p_a/p_b = .77/.61 = 1.26$. Now the relevance of this price ratio is debatable, because milk is not processed for sale exclusively as these components. As an alternative, component prices were calculated as the weighted average of the prices of milk products, with the fraction of the component sold via each product as weights. This yielded $p_a/p_b = .59/.46 = 1.13$.

Table 3. Butterfat versus Two-Component Pricing Equilibria in the Federal Order Milk Markets

Endogenous Variable	Symbol	Butterfat Pricing Equilibrium	Two-Component Pricing Equilibrium $e = 0$, $\tau = -0.5$	$e = 2.5$, $\tau = -.5$	$e = 2.5$, $\tau = -1.5$
Milk production (billion lbs.)	Q	69.46	69.46	69.26	69.17
Butterfat production (billion lbs.)	A	2.55	2.47	2.47	2.43
Solids-not-fat (SNF) production (billion lbs.)	B	5.98	6.09	6.07	6.12
Farm price of milk (\$/lb.)	p	.0867	.0866	.0866	.0866
Price of butterfat (\$/lb.)	p_a	.77	.816	.819	.844
Price of SNF (\$/lb.)	p_b	.63	.601	.605	.594
Farm price of butterfat (\$/lb.)	w_a	.900	.862	.846	.874
Farm price of SNF (\$/lb.)	w_b	.623	.646	.646	.634
Farm value of milk (\$ billion)		6.02	6.07	6.00	5.99
Value of components (\$ billion)		5.73	5.68	5.70	5.68
Change in:					
Producer surplus (\$ billion)			.047	−.007	−.010
Butterfat consumer surplus (\$ billion)			−.115	−.123	−.184
SNF consumer surplus (\$ billion)			.173	.148	.216
Net social surplus (\$ billion)			.105	.018	.022

Sources: USDA *Federal Milk Order Market Statistics, Annual Summary for 1977*. Figures are averages for the three market years 1974–76. Solids-not-fat production was calculated using the average content of all milk produced in the United States for those years (USDA *Dairy Situation*, May 1978). The price of butterfat is the average U.S. price reported for milkfat in cream, and the price of SNF is the average U.S. price for nonfat dry milk for those years, both as reported in *Agricultural Statistics, 1977*. The farm prices for components are calculated as described in the text from 3.5% butterfat blend price, total revenue and butterfat content as reported in *Federal Milk Order Market Statistics*.

Both of these sets of prices imply that the total value of the butterfat and SNF components of milk is less than the farm value, evidence of the oversimplification of the two-component model used here. But because these two estimates of the ratio do not differ greatly, for this analysis we estimate that the ratio of consumer prices for the two components is about 1.2. In any case, it appears that the current pricing structure overprices butterfat, the more valuable of the two components. The price wedge is about 1.4/1.2 = 1.17, which suggests that a shift to component pricing would result in a 20% reduction of ρ.

Estimates of the demand elasticities for the two components are not available. They have been calculated for purposes of this study as the weighted average of the elasticities of demand for the products in which they are sold, using the Hallberg-Fallert product-elasticity estimates and the share of component sold via each product during 1974–76 as weights. This procedure yielded estimates of −.5 as the demand elasticity for butterfat and −.4 for SNF. For supply elasticity, we use the Chen, Courtney, and Schmitz estimate of 2.5. As was the case for soybeans, there have been no studies of the elasticity of transformation between fats and protein in milk production. The Ontario Milk Marketing Board report cites many studies of factors affecting milk composition, but concludes only that transformation opportunities are limited at best and can only be achieved slowly (p. 2–5). Given this lack of empirical estimates, we will again consider alternative transformation elasticity estimates of −.5 and −1.5.

The impact on prices and quantities, in percentage terms, of a change from butterfat pricing to two-component pricing is shown in table 4. Equilibrium values are compared in table 3. Butterfat production is estimated to fall by at most 3% to 5% and SNF production to rise by at most 2%, with corresponding changes in component prices. Losses to butterfat consumers would be up to $184 million, about 9% of the current value of the component, while gains to SNF consumers would be up to $216 million, about 6% of the value of the component. Producers would gain in the case of fixed inputs, because production is diverted to the more price inelastic market, but not in the other situations. The annual increase in social surplus would not exceed $105 million, or about 2% of the value of milk production, less the extra costs of implementation. As was the case for soybeans, it appears that the potential improvement in net social gains is small, though there could be substantial transfers between consumer groups and perhaps among producers as well.

Summary

The general objective of this paper has been to determine the potential impact on producers and consumers of a movement toward more

Table 4. Percentage Equilibrium Displacement from Two-Component Pricing of Milk

Endogenous Variable	Symbol	Displacement of Equilibrium Values from Butterfat Pricing to Two-Component Pricing		
		$e = 0$, $\tau = -.5$	$e = 2.5$, $\tau = -.5$	$e = 2.5$, $\tau = -1.5$
		(%)		
Milk production	Q	0	−0.29	−0.42
Butterfat production	A	−2.96	−3.18	−4.80
Solids-not-fat (SNF) production	B	1.82	1.56	2.27
Farm price of milk	p	0.78	−0.12	−0.17
Price of butterfat	p_a	5.92	6.37	9.60
Price of SNF	p_b	−4.55	−3.91	−5.68
Farm price of butterfat	w_a	−4.19	−6.02	−2.92
Farm price of SNF	w_b	3.64	3.70	1.79
Change in social surplus as a percent of value:				
Producer surplus		0.78	−0.12	−0.17
Butterfat consumer surplus		−5.84	−6.27	−9.38
SNF consumer surplus		4.59	3.93	5.74
Net social surplus		1.8	0.3	0.4

accurate component price transmission from consumers to producers in the soybean and milk markets. To describe the potential equilibrium displacements which would result from such changes, a market model was specified in which two components are produced jointly with constant elasticity of transformation, and in which the producer component price ratio and the consumer price ratio are separated by an exogenous wedge representing the accuracy of price transmission. It was shown that the size of the equilibrium displacement depends upon the elasticities of demand for the components, the elasticity of supply of the commodity, and the elasticity of transformation.

Under current soybean-pricing practices, farmers implicitly receive the same price per pound for oil and for protein; while in the component markets, a pound of soybean oil is worth about one-third more than a pound of soybean protein. The implementation of component pricing of soybeans at the farm level would have a negligible effect on producer returns, and would increase social surplus by an amount up to $125 million per year (about 1.4% of the value of the crop). Under current milk pricing practices, farmers receive an implicit price per pound for the fat component that is about 40% higher than the implicit price per pound for the solids-not-fat component. In the component markets, fat is also worth more per pound than solids-not-fat, but only about 20% more. The difference between these two figures reflects the extent to which the current butterfat-based milk pricing system overprices fat relative to solids-not-fat. The implementation of two-component pricing would appear to affect producer returns little if at all, and would increase social surplus by an amount up to $105 million per year (about 2% of the value of milk production).

The results of this analysis suggest that the social benefits attainable from the component pricing of soybeans and milk are small at best, being no more than one or 2% of the current value of these commodities. There are several reasons to believe that the gains would be smaller than even this estimate. First, the limited data available on the technological possibilities for changing component composition of milk and soybeans suggest that the transformation elasticity may be quite small compared to the estimates used here. Second, the additional transactions and monitoring costs for component pricing have not been deducted from these estimates, and we might well infer that these costs have been of sufficient importance in the past to discourage the adoption of component pricing by market participants. Third, the equilibrium analysis employed here has assumed that producers would know the component price ratio in advance of production decisions. To the extent that variations in this price ratio would lead to wrong expectations, the efficiency gains realized would be diminished.

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References

Brandow, G. E. *Interrelations among Demands for Farm Products and Implications for Control of Market Supply*. Pennsylvania State University Agr. Exp. Sta. Bull. 680, 1961.

Chen, Dean, Richard Courtney, and Andrew Schmitz. "A Polynomial Lag Formulation of Milk Production Response." *Amer. J. Agr. Econ.* 54(1972):77–83.

Christensen, Laurits R., Dale W. Jorgenson, and Lawrence J. Lau. "Transcendental Logarithmic Production Frontiers." *Rev. Econ. Statist.* 55(1973):28–45.

Gardner, Bruce. "Futures Prices in Supply Analysis." *Amer. J. Agr. Econ.* 58(1976):81–84.

Hallberg, M. C., and R. F. Fallert. *Policy Simulation Model for the U.S. Dairy Industry*. Pennsylvania State University Agr. Exp. Sta. Bull. No. 805, 1976.

Hirshleifer, J. "The Private and Social Value of Information and the Reward to Inventive Activity." *Amer. Econ. Rev.* 51(1971):561–74.

Houck, J. P. *Demand and Price Analysis of the U.S. Soybean Market*. University of Minnesota Agr. Exp. Sta. Tech. Bull. No. 244, Minneapolis, 1963.

Houck, J. P., M. Ryan, and A. Subotnik. *Soybeans and Their Products: Markets, Models and Policy*. Minneapolis: University of Minnesota Press, 1961.

Kihlstrom, Richard. "A Bayesian Model of Demand for Information about Product Quality." *Int. Econ. Rev.* 15(1974):99–118.

Ladd, George W. *Research on Product Characteristics: Models, Applications and Measures*. Iowa State University Agr. Exp. Sta. Res. Bull. 584, 1978.

Muth, Richard F. "The Derived Demand Curve for a Productive Factor and the Industry Supply Curve." *Oxford Econ. Papers* 16(1964):221–34.

Niernberger, Floyd F. *Near-Infrared Reflectance Instrument Analysis of Gain Constituents: A Cost Study*. Washington, D.C.: USDA ESCS-20, 1978.

Ontario Milk Marketing Board. *Multiple Component Testing and Pricing of Milk in Ontario*, part 2. Toronto, Ontario, 1976.

Smith, B. J., and S. D. Snyder. "Effects of Protein and Fat Pricing on Farm Milk Prices for the Five Major U.S. Dairy Breeds." *Amer. J. Agr. Econ.* 60(1978):126–31.

Spence, A. M. "Competition in Salaries, Credentials and Signalling Pre-requisites for Jobs." *Quart J. Econ.* 90(1976):51–74.

Updaw, Nelson. "Market Analysis of the Component Pricing of Soybeans." Ph.D. thesis, North Carolina State University, 1979.

Updaw, Nelson, and T. E. Nichols. "Pricing Soybeans on the Basis of Chemical Constituents." *Proceedings,* World Soybean Conference II, North Carolina State University, Raleigh, 26–29 Mar. 1979.

U.S. Department of Agriculture. *Agriculture Statistics, 1977.* Washington, D.C., 1978.

———. *Dairy Situation,* DS370. Washington, D.C., 1978.

———. *Fats and Oils Situation,* FOS-293. Washington, D.C., 1978.

———. *Federal Milk Order Market Statistics, Annual Summary for 1977.* Statist. Bull. No. 611, Washington, D.C., 1978.

Willig, Robert D. "Consumer's Surplus Without Apology." *Amer. Econ. Rev.* 66(1976):589–97.

Optimal Policies for Marketing Cull Beef Cows

William A. Yager, R. Clyde Greer, and Oscar R. Burt

Feeding and marketing strategies for cull beef cows were analyzed by formulating a stochastic dynamic programming model which allowed simultaneous determination of optimal selling time and feeding levels until sale. The state variables were cow weight and monthly price; the latter was estimated statistically as a first-order autoregressive process with parameters changing monthly. Results for Montana cow prices at Billings suggested substantial gains to feeding healthy cows through the winter instead of immediate sale after fall culling.

Key words: cull beef cows, dynamic programming, marketing alternatives.

Livestock marketing research has focused almost solely on the primary product of the beef cow-calf subsector, stocker and feeder cattle, while marketing the important joint product, cull brood cows, has received little attention. Beef cows are purchased and held for their value as productive assets. At the time cows are removed from the breeding herd, there are marketing alternatives; yet seasonal selling patterns suggest that once removed from the breeding herd, cows are disposed of immediately. If the firm is, in fact, attempting to maximize net return, then consideration of marketing alternatives for cull cows is worthy of attention because they constitute 15% to 25% of annual gross revenue.

At the time a cow is removed from the brood herd, her current market value, price times weight, is known within rather narrow limits. Slaughter cow prices at local auctions and terminals are known, and prices offered by country buyers, both packer buyers and speculators, can be discovered readily. While spatial price differences may exist, increased net returns usually cannot be realized by individual producers because of increasing transaction and transport costs for the relatively small lots sold (Erich, Glandt, St. Clair).

Marketing alternatives which might yield increased net returns would take advantage of existing patterns of seasonal price variation and the ability of cull cows to maintain body condition and achieve weight gains on high roughage rations. As is the case with many agricultural product price series, cull cow prices have exhibited very definite patterns of seasonal variation. Larson; Erich, Glandt, St. Clair; and Plaxico and James all report significant patterns of seasonal variation in slaughter cow prices. Prices are at their seasonal low in late fall and seasonal high in the spring. Larson concluded that slaughter cow marketing has not changed to reduce swings in seasonal variation to the extent that such changes have occurred among other livestock enterprises.

The methods of Foote and Fox were applied to fifteen years of slaughter cow-price data from the Billings, Montana, market (December 1960 through November 1975), and similar significant patterns of seasonal variation were found for each of the four slaughter cow grades, table 1. Prices were at their seasonal low in November and their peak in May or June, with the difference between the high and low price as much as 19% of the annual average price.

Seasonal price patterns, at least in large part, result from current marketing decisions. In many regions of the United States, and particularly in the range livestock areas, beef cows are bred to calve in the spring. Under a system of spring calving ranchers are most likely to cull cows in certain seasons; many old, poor-producing, or open cows are culled in late autumn when calves are weaned. Other

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Table 1. Indices of Seasonal Variation, Slaughter Cow Prices, Billings, Montana

Month	Commercial Cow Price	Utility Cow Price	Canner Cow Price	Cutter Cow Price
January	.9600	.9563	.9427	.9247
February	1.0069	1.0061	.9956	.9797
March	1.0458	1.0455	1.0436	1.0301
April	1.0497	1.0520	1.0528	1.0509
May	1.0499	1.0601	1.0675	1.0655
June	1.0353	1.0487	1.0640	1.0775
July	1.0138	1.0220	1.0393	1.0563
August	1.0250	1.0129	1.0412	1.0579
September	1.0144	1.0174	1.0127	1.0244
October	.9631	.9566	.9425	.9487
November	.9052	.8967	.8884	.8886
December	.9308	.9258	.9097	.8957
Calculated F-Statistic	3.96*[a]	5.07*	7.10*	7.55*

[a] Asterisk indicates significance at the 5% level.

cows are culled in the spring after failing to calve or losing their calves or to adjust herd size as range conditions vary within a year. These production characteristics combined with immediate sale at culling result in significant seasonal shifts in cow supply.

Cows sold immediately at culling will be in a given body condition, depending upon the balance between feed nutrients provided and required during the immediately preceding period, which for cows culled in the fall is the calf-suckling period and for those culled in the spring is the wintering period when cold stress and later stages of gestation increase nutrient requirements. Only significant changes in management practices would provide an opportunity to alter body condition of cows at culling. However, with delayed sale alternatives, there is an opportunity to alter body condition and weight by providing alternative levels of nutrition to cows that have been culled and will be sold.

Marketing alternatives that delay sale increase costs and introduce risk and uncertainty into the problem. Additional costs for feed, labor, facilities, opportunity cost of capital, and sickness and death loss will be incurred during the holding period. The major cost is feed, which varies with cow body weight and desired weight change. Heavy cows require more feed for body maintenance, and cows of a given weight require relatively higher levels of nutrition to achieve rapid weight gain. Delaying sale and feeding for one of several rates of gain will be a preferred alternative only if returns are expected to increase. The return, which is jointly determined by unknown future values of two variables, cow price and cow weight, will be received as a lump sum when the cows are sold.

The discussion thus far had focused on seasonal price variation as the primary motive for delayed sale, but insofar as the long-term cyclical behavior of cattle prices can be forecast with sufficient accuracy, additional profits would be possible on the rising price period of the cycle. On the other hand, the falling price period of the cycle would reduce the opportunities of profiting from the typical seasonal increase in prices during winter months.

The purposes of this paper are (a) to develop an appropriate decision model for evaluating cull beef cow-marketing strategies, and (b) to present an application which suggests the magnitude of potential expected profits and general structure of the optimal decision rule. The relative order of magnitude of expected gains from a formal decision model compared to immediate sale of cull cows will indicate whether empirical refinements are worthy of attention.

The Decision Model

Evaluation of cull cow-marketing alternatives is considered properly in a stochastic framework because both weight gain and future prices are random variables. The marketing decision, what to sell, in terms of body weight increments, and when to sell, depends upon price and weight change expectations which are formed under the joint probability distribution of price-weight change. Further, there are

characteristics which suggest that the problem is properly formulated as a sequence of decisions rather than a once-and-for-all decision. It is, of course, the case that once a cow is sold there is nothing more that can be done to affect the return from that cow. But while a cow is being held after culling, changing conditions may well affect the return from previous decisions as well as expectations in such a way that another decision, feeding at a different level or selling immediately, is preferred over previous plans.

The cull cow-marketing problem is thus a stochastic dynamic decision process which at any point in time is summarized by values of certain critical variables—state variables—that completely describe the system. While there may be a relatively large number of variables necessary to describe completely the cull cow-marketing problem, it is argued here that two variables, cow price and cow weight, adequately describe the process. These two variables define cow value, and are continuous variables which, in the course of time, take on different values. With each new value of one or both variables—state transition—the system occupies a different state.

Thus, the decision maker considers current known values of two continuous variables as well as the conditional probability distribution for their future values. In cases where such uncertainty is important, it is often beneficial to delay decisions as long as possible, allowing results of previous decisions and changed values of state variables to be observed and incorporated into the decision process. In the present problem, for example, after cows are removed from the breeding herd, a choice between selling or holding must be made. If the choice is to hold, then a specific level of nutrition also must be selected. However, rather than prespecifying the length of the holding period and a level of nutrition for the entire period, at succeeding intervals—stages—state variables are observed, and these values serve as information in the decision process. The states are random and jointly distributed over time, such that each observation in time is information regarding the state that will occur next. At each point in time that new information relevant to the decision problem is received (stage of the process) a choice is made between selling or holding the cows; and if the decision is to hold, then a level of nutrition also must be selected. Thus, the problem is viewed properly as a sequential decision process.

Ladd and Williams have recognized the dynamic stochastic nature of the cattle-feeding problem in their investigation of feedlot management where a Bayesian decision model was selected as the method of analysis. While the states and stages specified were quite similar to those of the present problem, the number of possible states and stages was restricted severely because total enumeration of all possible state/stage combinations was used as a method of solution. The computational burden of this approach is obvious.

Dynamic programming, through the inductive backward solution technique, has been shown to be a robust, computationally efficient method for solving stochastic multistage decision processes under an expected value criterion. Determining an optimal decision rule for all possible initial states at the first stage of the process also determines an optimal policy for all states and stages of the process (Burt and Allison). Hence, with a one-year planning horizon, a dynamic programming solution to the rancher's cull cow-marketing decision in the fall will yield optimal marketing policies for cows that might be culled at any time during the year.

It would appear that an expected value criterion is appropriate for the cull cow-marketing problem because the net returns are small relative to the entire ranching operation. The associated variations under different marketing policies would constitute small enough changes in the rancher's wealth that a linear approximation to the utility function could be used without serious error.

Specification of stage length is quite arbitrary, but the model becomes increasingly complex as the stage length is shortened. We compromised by using a month. The actual structure of the model depends on the statistical behavior of the monthly price series used to estimate the probability distribution of future prices. The data suggested a first-order autoregressive relationship with separate parameters by months.

The recurrence relation of the stochastic dynamic programming formulation is

$$(1)\quad V_t(P,W) = \max\left\{PW, \max_k\left[-C(k,W) + \beta\alpha\int_0^\infty\int_{-\infty}^\infty V_{t+1}(X,W + 30G)h(G|W,k)f_{t+1}(X|P)dGdX\right]\right\},$$

where P is average cow price for the month

just ended; W is cow weight; G, daily rate of gain produced by the feeding level chosen; $C(k,W)$, cost of feed, labor, and facilities for the cow weight and feeding level chosen; $h(G|W,k)$, the conditional probability density function of gain, given cow weight was W and level of nutrition k; $f_t(X|P)$, the conditional probability density function of cow price, X, in month t given price in month $t - 1$ was P; α, probability that a cow will live one more month; β, discount factor, $1/(1 + i)$; t, month, 1 = November, 2 = December, . . . ; and k, decision alternative with respect to feeding level.

When the maximum in (1) is PW, the process makes a transition to a terminal state where $V_t(\cdot)$ is identically zero for any period t. Although we have α factored out from under the integral, the joint probability density function for the present value, $V_{t+1}(X, W + 30G)$, is $\alpha h(G|W,k)f_{t+1}(X|P)$, and $V_{t+1}(\cdot)$ assumes the value zero with probability $1 - \alpha$. The value PW appearing in (1) implies that a cow can be sold at the beginning of a month for the average price prevailing during the month just past. Within the limits of the discrete time model using a stage length of a month, this assumption seemed as reasonable as the only practical alternative of using expected price during the month just being entered.

The double maximization operation in (1) can be interpreted as follows. If the cow were to be kept one more month, the maximization with respect to k (the feeding intensity) would be necessary and the associated value appearing in (1) would be the expected present value of the cow if she were kept another month and an optimal policy followed thereafter. This value must be compared with PW, the expected present value from immediate sale; the maximum of these two values is $V_t(P,W)$.

The Empirical Problem

Twelve stages were specified with each stage corresponding to a month thirty days in length. The initial stage was November which, within the dynamic-programming solution technique, is the last stage of the computations. Under present management practices, November is the month in which the largest proportion of cows are culled and sold in Montana. Thus, the model determines optimal decisions for cull cow marketing in any month from November through the following October. The decisions are optimal subject to the condition that the cows must be sold by the end of October.

States

State variables describe the condition of the decision process and thus constitute the vector of attributes that determine current and future cow value. Current value is determined by cow price and cow weight which suggests these two variables as state variables. However, there may be additional information that is important to describing precisely the condition of the process and the transition of these two critical variables over time.

Cow weight depends upon health of the cow and her performance, as measured by the achieved rate of gain on the level of nutrition provided. At culling, some cows may be in poor health and their performance through the holding period would be different than the norm. While experimentation could provide the necessary death loss and rates of gain estimates, they are not currently available. In this study expected sickness and death loss and rates of gain were assumed to be constants. Thus, the results apply to healthy culled cows with the presumption that unsound cows would be sold immediately at culling.

Cow price is an essential variable for establishing value of the cull cow when ultimately sold. Any variables that help predict price one month ahead are candidates for state variables, in principle at least. For this study we selected a time-series approach to predicting future cow price rather than constructing a model that explicitly accounts for the determinants of supply and demand. Several specifications which included both autoregressive and moving-average terms after seasonal differencing (Box and Jenkins) were estimated using monthly average commercial cow prices reported from Billings, Montana, January 1960 through May 1976. A simple first-order autoregressive model which allowed both slope and intercept parameters to vary by month gave better results (standard error of the estimate equal 0.928) than the best model using the techniques of Box and Jenkins (standard error of the estimate equal 1.05). The first-order autoregressive equation was tested by predicting twelve months beyond the sample period and the root mean-square error of prediction was less than the standard error of the estimate from the regression equation. De-

flated cow prices gave a poorer fit and less precision than the raw data.

Since the primary objective of the study was to evaluate potential expected profits from cow disposal strategies, as contrasted to deriving practical decision rules, we did not pursue the forecasting research in much depth. In retrospect, we should have tried a logarithmic transformation of the data because the resulting model would have been more robust to changes in value of the dollar.

First-order autoregressive processes can track a cyclical sequence like we find in the cattle industry quite well if the cycle is long relative to the discrete time period being used. In monthly data, the cattle cycle would typically be 120 to 140 periods; therefore, the first-order process should not be seriously disadvantaged by the cattle cycle. The statistical analysis supported this conclusion with higher order lagged prices being quite insignificant.

Because the first-order autoregressive model elicits most of the information contained in the past prices, only one price state variable, current cow price, is necessary. The estimated equation was used to generate conditional probabilities for future observations (Nelson, pp. 18–19).

Feed prices can best be treated as a parameter instead of a state variable in the decision model for three reasons: (*a*) seasonal variation is relatively small in feed as compared to cow prices; (*b*) a short-term variation in cow price has a great deal of leverage on profit because the entire weight of the cow enters total revenue, while feed price only affects the profit margin during the time on feed, i.e., a quick sale can prevent losses when feed price goes up sharply but not when cow prices drop sharply; and (*c*) changes in feed prices can be hedged period by period as a decision is made to hold the cows on feed another period. These considerations make it possible to model the cow disposal problem with feed price as a parameter and solve the entire dynamic programming problem several times for various feed price levels. Then the decision rule, period by period, could be modified to include feed price as if it had been another state variable.

The tacit assumption in doing so is that feed price will be constant throughout the planning horizon, but as new information on feed price evolves, a new feed price can be assumed for the remainder of the process. Formally, we assume that feed price is a stationary first-order Markov process which is independent of other state variables and then apply a certainty equivalence approximation to that component of the decision model (Malinvaud). The certainty equivalence theorem would apply if feed price entered the expected immediate return function as a quadratic jointly with the decision variable, given the other state variables, but otherwise, only approximately. The stationarity assumption on feed price is also only approximate insofar as some seasonal price variation exists.

For purposes of this study, feed prices were collected through an informal survey of feed dealers and farmers and were assumed constant throughout the decision process.

Thus, two state variables, cow weight and cow price, describe the process at the beginning of a month under the assumptions stated above. Cow weight and cow price are both continuous variables but for computational purposes were divided into discrete units which were, hopefully, small enough to maintain the spirit of continuity. Cow prices within the range \$10.00 to \$30.00 per hundredweight (cwt.) were considered and divided into \$0.25 intervals. Thus, there were eighty-one possible prices: \$10.00, \$10.25, . . . , \$29.75, \$30.00. Cow weights within the range of 350 kilograms (kg.) to 597.5 kg. were considered and divided into intervals of 7.5 kg. Thus, there were thirty-four possible weights: 350.0 kg., 357.5 kg., . . . , 590.0 kg., 597.5 kg. The number of states was the number of discrete cow weights times the number of discrete cow prices, 2,754 (81 times 34), with state number one assigned to the combination cow weight 350.0 kg. and cow price \$10.00/cwt., state number 2 assigned to the combination cow weight 350 kg. and cow price 10.25/cwt., ... An additional state, number 2,755, described the state of the process when cows were already sold.

Decision Alternatives

The decision made in one stage controls the state of the process in the following stage. For any stage after a decision to sell cows has been made there are no alternatives and the decision process is terminated. Otherwise, one possible decision at any stage is to sell the cows. Alternatively, the decision may be to hold cows for later sale, in which case a decision must be made regarding the ration to feed. While rate of gain is assumed constant,

Table 1. Comparison of Time Series with Frisch Method Estimates of Demand Price Elasticities for Three Levels of Commodity Aggregation

Commodity	Time Series	Frisch	Commodity	Time Series	Frisch
		Group One			
Durables	−1.23	−1.23	Nondurables	−0.62	−0.62
Semi-durables	−0.69	−0.69	Services	−0.91	−0.92
		Group Two			
Food	−0.42	−0.48	Drugs and sundries	−0.78	−0.92
Tobacco and alcoholic beverages	−0.54	−0.64	Transportation and communication	−1.00	−1.15
Clothing	−0.52	−0.60	Recreation, entertainment, education, and cultural services	−1.09	−1.27
Gross rent, fuel, and power	−0.74	−0.84			
Furniture, furnishings, household equipment, and operations	−0..72	−0.83	Personal goods and services	−0.55	−1.27
		Group Three			
Beef	−.8522	−.4008	Margarine	−.6276	−.0786
Pork	−.9547	−.1053	Lard	−.4628	−.0769
Lamb	−1.8660	−.5203	Shortening	−.9680	−.1703
Veal	−2.5930	−.3966	Salad dressing	−.9270	−.2280
Chicken	−.5637	−.1156	Fresh fruits	−.4546	−.1754
Turkey	−1.0900	−.3993	Canned fruits	−.7498	−.3093
Fish	−.7929	−.1678	Fresh vegetables	−.2420	−.0702
Eggs	−.1207	.0000	Canned vegetables	−.3215	−.0837
Cereals	−.2000	−.1275	Sugar	−.2400	−.0909
Fluid milk	−.4390	−.1617	Beverages	−.3726	−.1210
Butter	−.8583	−.2222	Frozen foods	−1.0319	−.4134
Cheese	−.9077	−.4016	Prepared foods	−.6710	−.2544
Skim milk powder	−.1924	.0000	Miscellaneous foods	−.1244	−.0280
Other dairy products	−.3300	−.0853			

Source: Frisch estimates were calculated by the authors based on Frisch [p. 186, eq. (61)] and income elasticity, budget proportion, and money flexibility (−1.30) estimates from Green et al. (pp. 100, 104) for groups 1 and 2 and Hassan and Johnson (1976, p. 41) for group 3 from which the comparable time-series estimates were also obtained.

suggestions by Houthakker, it appears that at both of these aggregation levels, the assumption of want independence would be valid.

At the bottom of table 1, it is apparent that the Frisch estimates differ substantially from the time series estimates for the individual food commodities or food groups. Of the twenty-seven time series price elasticities estimated, nine are directly from the regression analysis by Hassan and Johnson (1976). Of these, no Frisch-calculated elasticity is within one standard deviation of the respective time-series elasticity and only two (fish and canned fruits) are within two standard deviations. Slightly different time-series price elasticity estimates and standard deviations (from those ultimately used in the complete matrix) are reported by the authors for ten additional commodities. Of these, only the Frisch-calculated elasticity for eggs is within two standard deviations of the time-series estimate and none is within one standard deviation. If the differences between the Frisch and the time-series elasticities using the Canadian data are indicative of what is likely to occur with highly disaggregated commodities or groups, the Frisch method used by P-L-H appears to be inappropriate. The downward biased estimates agree with earlier theoretical analysis regarding the consequence of ignoring the combined effects of goods that are likely to be substitutes under non-want independence.

For a commodity whose budget proportion is low, e.g., most individual food commodities, the Frisch price elasticity has been shown to be approximated by the income elasticity divided by the money flexibility coefficient (Barten 1977, and Deaton). Given that most values of θ generated have typically been between −1 and −2 (Brown and Deaton, p. 1206), the use of this approximation generates price elasticities that are less (in absolute value) than their income elasticities. In fact, for individual food commodities, theory and empirical evidence would suggest that the converse is more likely true. Yet, in their two articles in this *Journal*, Pinstrup-Andersen and others present tables of

of the direct price elasticity calculated with the Frisch approach from the true e_{ii} will equal $\sum_{k,k \neq i} \sigma_{ik}$. Ayanian (p. 85) noted, "The possibility that, in the absence of want independence, $\sum_{k,k \neq i} \sigma_{ik} = 0$ (i.e., that the effects of complementarity just offset all substitution effects related to good i) would seem to be very small." If good i is a substitute of several other goods (as is likely to be the case for individual food commodities, e.g., beef, pork, eggs, etc.), then $\sum_{k,k \neq i} \sigma_{ik}$ will be greater than zero and the Frisch estimates will be biased. To ignore these combined effects because of the assumption of want independence would lead to estimates which are below the true elasticities. Ayanian found this to be in accord with Barten's (1964) findings that twenty of the twenty-two nonzero utility interactions were substitutions.

The calculation of the matrix of demand price elasticities requires estimates of the income elasticities, budget proportions, and the flexibility of money, θ. The method by whch P-L-H calculated θ is from Frisch's (p. 187) equation (64), which itself is based upon the assumption of want independence. The authors' six food commodities—rice, beans, tomatoes, oranges, sugar, and cooking oil—used for calculating θ are unlikely want independent. It is questionable whether the procedure was "certainly the best available, given the data constraints" (p. 136). Other methods are available for estimating θ. Although Bieri and de Janvry did not report an estimate for Colombia (as noted by the authors), estimates were available for other South American countries (Chile, Argentina). These estimates were higher (in absolute value) than the one finally chosen by P-L-H. De Janvry, Bieri, and Nuñez also suggest a formulation for estimating θ which the authors recognized but rejected because of exchange rate problems between countries. Whether the method suggested by de Janvry, Bieri, and Nuñez would have resulted in an estimate of θ that is poorer than one calculated with commodities which are not likely to be want independent is a question worth considering. More recently Lluch et al., suggested a formula for estimating θ based on national accounts data.

P-L-H's (p. 136) conclusion that their estimate of θ is below what would be expected from previous estimates of other countries and, furthermore, that it is inconsistent with Frisch's conjecture that the absolute value of θ decreases as the level of real income increases should cause them to suspect the applicability of using six individual food commodities for its estimation. The assumption of want independence is just not likely to hold at this level. Ayanian concluded that Frisch-calculated elasticity estimates were quite sensitive to decreasing values of θ, and that in particular the direct elasticities are likely to be $(n - 1)$ times more sensitive to errors in θ than are the cross-elasticities where n is the number of sectors (commodities) analyzed. If one has several estimates of θ, Ayanian has shown that the higher (absolute) estimates should be weighted more heavily in averaging to reduce the expected error.

In an attempt to evaluate empirically the appropriateness of the want independence assumption, we have calculated demand price elasticities of commodities (or groups) at three levels of aggregation using the Frisch method. These results are then compared with price elasticities estimated from time-series data. To the extent that the want independence assumption is correct, the resulting elasticity estimates using the Frisch approach should approximately agree with what one would estimate statistically if adequate time-series data were available.[1] It is usually not possible to judge the reasonableness of the Frisch-generated estimates, particularly in developing countries, because estimates from time-series data are not available as was the case in the P-L-H study.

Recent articles by Green, Hassan, and Johnson provide time-series estimates of price and income elasticities for (*a*) four highly aggregated groups of commodities—durable goods, semidurables, nondurables, and services, and (*b*) nine slightly less aggregated commodity groups, and by Hassan and Johnson (1976) for (*c*) twenty-seven individual food commodities or food groups similar to those in the P-L-H study in terms of their level of aggregation. An estimate of the flexibility of money of -1.30, which is used in the calculations below, was obtained for the four aggregated groups where the want independence assumption is likely to be valid.[2]

In table 1, estimates of the direct price elasticity from time-series data can be compared with those calculated using the Frisch method. It is readily apparent that the Frisch coefficients are nearly the same as their respective time-series values for the four most aggregated commodity groups suggesting that the Frisch method does quite well. For the middle aggregation level, the price elasticities calculated with the Frisch approach differ somewhat from the time-series estimates although in most cases, these differences are quite small.[3] Based on

[1] This, of course, assumes that elasticities generated from econometric demand models using time series are the "true," or closer to the "true," elasticity estimates. As O'Riordan showed, the results from various statistical demand models can themselves vary substantially; that is, estimates of a commodity price elasticity may vary due to different time periods, functional forms, or model specifications. Typically, however, time-series rather than cross-section or budget data are thought to provide researchers with better measures of systematic changes in prices and quantities for demand elasticity estimation.

[2] The estimated income flexibility (the inverse of the money flexibility, θ) reported was more than three times its standard error.

[3] Because Green et al., did not provide standard deviations for their estimates, no tests of statistical significance could be performed; however, due to the small differences it is unlikely that the Frisch estimates are statistically different from the time-series estimates.

The Impact of Increasing Food Supply on Human Nutrition—Implications for Commodity Priorities in Agricultural Research and Policy: Comment

Jon A. Brandt and Joseph B. Goodwin

In a recent article in this *Journal,* Pinstrup-Andersen, de Londoño, and Hoover (P-L-H) estimated demand price elasticities for Cali, Colombia, using the method developed by Frisch. From these estimates the authors proceeded to examine the changes in the nutritional levels (measured in calories and protein) of different population income strata from shifts in individual food commodity supplies. As with all studies, the conclusions and implications from the results are influenced by the choice of analytical method. This comment examines in somewhat greater detail (than did P-L-H) the Frisch method, its appropriateness, and its limitations. We contend that the selection of the Frisch method by P-L-H for estimating demand price elasticities for individual food commodities was inappropriate and that the calculated price elasticities are likely biased.

The authors note that the Frisch method allows for the estimation (calculation) of a complete price elasticity of demand matrix. They also note that this process is based on the assumption of want independence among the commodities or groups of commodities considered, and that this assumption is not valid for all goods. P-L-H (p. 133) incorrectly state that "it may be possible, however, to group the bundle of goods available to the consumer to obtain little or no want independence among the groups," whereas, in fact, the reason for grouping goods is to obtain little or not want dependence.

A review of the literature regarding the Frisch method leads to but one conclusion: the assumption of want independence is likely to be true only for broad aggregate groups. Deaton criticizes the Frisch method because of the restrictiveness of the want independence assumption, which implies direct additivity of preferences. Houthakker suggests that the additivity assumption is most likely applicable with large aggregate groups such as clothing and food. Barten (1968) uses the Frisch approach to estimate price elasticities for such broad groups as food, pleasure goods, and durables. None of these studies indicate that the method is applicable at the individual commodity level. In fact, Frisch did not suggest that the approach be used at the disaggregated level; rather he recommended its use to estimate elasticities for broad commodity groups where the assumption of want independence seems more valid.

Ayanian has shown that biased estimates of price elasticities will result if the want independence assumption is not applicable. The bias is due to the utility interaction of commodity i with all other goods for which i is non-want independent. This is illustrated starting with Frisch's (pp. 183, 4) formulas:

$$e_{ii} = \sigma_{ii} - W_i E_i\left(1 + \frac{E_i}{\phi}\right) \qquad (1)$$

$i = 1, \ldots, n$, and

$$E_i = \phi \sum_{k=1}^{n} \sigma_{ik}, \qquad (2)$$

where e_{ii} is the direct price elasticity for good i, σ_{ik} are the want elasticities defined by Frisch, W_i is the budget proportion for good i, E_i is the income elasticity for good i, and 0 is the money flexibility. Then rearranging equation (2),

$$\frac{E_i}{\phi} = \sum_{k=1}^{n} \sigma_{ik} = \sigma_{i1} + \sigma_{i2} + \ldots + \sigma_{ii-1} + \sigma_{ii} + \sigma_{ii+1} + \ldots + \sigma_{in}, \qquad (3)$$

$$\sigma_{ii} = \frac{E_i}{\phi} - \sum_{k,k \neq i}^{n} \sigma_{ik}. \qquad (4)$$

Substituting equation (4) into equation (1) obtains

$$e_{ii} = \frac{E_i}{\phi} - W_i E_i \left(1 + \frac{E_i}{\phi}\right) - \sum_{k,k \neq i}^{n} \sigma_{ik}, \qquad (5)$$

$$e_{ii} = -E_i\left(W_i - \frac{1 - W_i E_i}{0}\right) - \sum_{k,k \neq i}^{n} \sigma_{ik}. \qquad (6)$$

But the first term to the right of the equal sign in equation (6) is the same as P-L-H's (p. 132) equation (1) under want independence. With the assumption of non-want independence, the deviation

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are considered rational since they depend on the same things as suggested by economic theory and incorporate available information. Our test of whether the market is efficient is conducted within the context of a specific model of price determination. The test of market efficiency with a specific model utilizing rational expectations is indeed a strong one. Both the model and test are based on sound theoretical structure.

The Norm

Substantial portions of Pasour's criticisms appear to originate with his erroneous reference to our model as an "ideal norm." Such an error would rightly lead one to make reference to the nirvana approach. However, our model is established only as a norm for comparison, and nowhere do we refer to it as an "ideal." The model's role as only a benchmark is clearly established. The model is simple in design and at the same time attempts to reflect the aggregate mental process of the market. Thus, the model and the market should perform similar roles in price formation.

In addition, the phrase "futures prices . . . accurately reflect subsequent spot prices" when stated out of context may convey a different meaning than intended as it apparently did to Pasour. It is not expected that futures markets should exactly predict subsequent spot prices. Errors are expected because of the lack of information and uncertainty. The question is: Do the markets in their price formation reflect at least the information currently available? The only way to examine that is with a norm. An efficient market needs only to reflect currently available information. Our performance norm is only relative, and it is difficult to imagine it as being ideal to the point of ensuring an "imperfect institutional arrangement" (Pasour). We make no claim as implied by both Pasour and Panton that our model is "efficient," only that it be considered a norm for comparison.

We do not compare the futures market to other institutional arrangements for relative efficiency. Buying and selling on the futures market by commercial firms may well be more efficient than, say, forward cash contracting. Small firms have difficulty in assessing local dealer offers because of the lack of comparison and high search costs. If survival is the only criterion, futures markets and many traders easily pass the test. But survival is a limited notion of efficiency and not directly applicable to evaluating forward-pricing abilities. Futures markets transmit information to economic agents, informed and uninformed alike (Danthine, Grossman), and the question is: How reliable is that information? Grossman suggests the appropriate test is the mean-squared prediction error conditional on available information, an approach similar to ours. Hamburger and Platt utilize the technique also.

Finally, Pasour concludes by suggesting that an "econometric model can be used to increase the accuracy of futures markets." How he obtained that implication from our study is a mystery. Our model is not designed to improve forward pricing on the futures market, and the statement only punctuates Pasour's misinterpretation of LH and the role the model played. He follows the above statement by saying, when referring to the trading capability of our model, that "the proof of the pudding is in the eating." Although not the designated purpose of our model, given the simulated trading results noted above, we offer the bowl of pudding to Pasour virtually free of charge and wish him "bon appétit."

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References

Danthine, J. P. "Information, Futures Prices, and Stabilizing Speculation." *J. Econ. Theory* 17(1978): 79–98.

Grossman, S. J. "The Existence of Futures Markets, Noisy Rational Expectations and Informational Externalities." *Rev. Econ. Stud.* 44(1977):431–49.

Hamburger, M. J., and E. N. Platt. "The Expectations Hypothesis and the Efficiency of the Treasury Bill Market." *Rev. Econ. and Statist.* 57(1975):190–9.

Leuthold, R. M., and P. A. Hartmann. "A Semi-Strong Form Evaluation of the Efficiency of the Hog Futures Market." *Amer. J. Agr. Econ.* 61(1979):482–9.

Rausser, G. C., and R. E. Just. "Agricultural Commodity Price Forecasting Accuracy: Futures Markets versus Commercial Econometric Models." *Futures Trading Seminar*, vol. 6. Chicago: Board of Trade of the City of Chicago, in press.

Stigler, G. J. "The Xistence of X-Efficiency." *Amer. Econ. Rev.* 66(1976):213–6.

after the sow-farrowing reports are released, an average return of 125% of the initial margin deposit after commissions over four-month holding periods could have been generated. If the decisions were made relative to the sow-farrowing intentions report, investment returns of 141% over seven-month periods were possible. This even assumes that on bad trades, additional margin money was deposited until the contract matured. Hence, the marginal benefits are substantial, and if anything on the conservative side because bad trades were held. Although costs will vary for traders, the benefit/cost ratio will certainly be positive for most.

Thus, Pasour's statement: "Use of a norm which fails to take account of [benefits and costs] is almost certain to lead to an incorrect assessment of the efficiency of real world economic activity" is interesting. He offers no proof, but as demonstrated here, the "incorrectness" may be an underestimation of the inefficiency involved if the benefits far exceed the costs for more information. The bias can go both ways.

These returns are probably "in excess of returns justified by risk" (Panton), although not formally tested. Panton's sole criterion for rejecting the EMH is for our pricing model to "systematically identify opportunities for excess returns." This suggests one procedure among several for judging market efficiency. Intuitively, the above results justify EMH rejection based on Panton's criterion, and serve to strengthen our original conclusions.

Finally, Pasour states we found in our study that "more or better informed traders could improve the forward-pricing accuracy of the futures market." As noted below, Pasour takes statements out of context and misinterprets. We found the market to be inefficient and suggest a possible resolution to this might be more or better informed traders. That, of course, depends upon costs and benefits.

In actuality, our study, like most empirical studies, is a partial analysis. We design a framework and test if the market appears to be using all the information available to it. Market inefficiency can occur for many reasons, and costly information (uninformed traders) is just one of them. Other causes for inefficiency in markets which can be examined include: (*a*) irrational traders, (*b*) wealth limitations, (*c*) risk aversion, (*d*) misinterpretation of information, (*e*) transaction costs, and (*f*) imperfect capital markets (Rausser and Just). A comprehensive theoretical framework for examining all these possibilities has not yet been developed.

Criteria for Market Efficiency

Pasour and Panton raise concern with how to evaluate market efficiency and the EMH. Pasour's only concern is the benefit/cost ratio, and Panton states that our model has no theoretical basis. We argue that our basic criterion is valid. As Fama states, an efficient market is one "in which prices provide accurate signals for resource allocation"; that is, where people can make decisions "under the assumption that . . . prices at anytime 'fully reflect' all available information" (p. 383). Just the existence of a market does not guarantee its efficiency. We established clearly when reviewing previous research in LH that futures prices are in fact used as signals when allocating resources, and the issue then is whether the prices are reliable.

Our model is a test of the expectations hypothesis that futures prices provide unbiased estimates of the market's expectation of future spot prices. Formally, the price expectations hypothesis can be represented as

$$(1) \qquad {}_{t+j}FP_t = E_t({}_{t+j}CP),$$

or the current period's futures price for a contract maturing in $t+j$ is the current expectation of the subsequent spot price in $t+j$. Under the assumptions of an EMH, the investors use all available information in forming expectations. It follows that

$$(2) \qquad E_{t+i}\,({}_{t+j}CP) - E_t\,({}_{t+j}CP) = u_{t,i},$$

where $u_{t,i}$ is a random number reflecting information regarding future spot price ${}_{t+j}CP$ available in $t+1$ but not available at time t. For $i = j$, the above equation reduces to

$$(3) \qquad {}_{t+j}CP - E_t\,({}_{t+j}CP) = u_{t,j}.$$

Substituting (1) into (3) yields

$$(4) \qquad {}_{t+j}CP - {}_{t+j}FP_t = u_{t,j}.$$

The expectations hypothesis and efficient market model imply that the difference between the futures price in t and the spot price that evolves at $t + j$ is a random number, representing the receipt of new information.

It is an empirical question if the hypothesis holds, and we test it with a model where expectations incorporate all publicly available information and prices reflect these expectations. Obviously, inaccuracies of market expectations will occur because not all future information is known. New information comes forth every day. Perfect expectations are unreasonable because of uncertain outcomes. This is referred to as "necessary inaccuracies" of market expectations. What we attempt to identify is any excess imperfection over this minimum, or "objectionable inaccuracies." These can be ascertained by determining if futures price changes are predictable, which we demonstrate clearly that they are with the likely benefit/cost ratio being positive.

This approach is well-grounded in theory, and does not condemn all inaccuracies in forward pricing, but only those in excess of the imperfections necessitated by lack of future information. Testing whether the market utilizes current information is an appropriate norm and is a meaningful point of departure. The expectations reflected by our model

A Semi-Strong Form Evaluation of the Efficiency of the Hog Futures Market: Reply

Raymond M. Leuthold and Peter A. Hartmann

Pasour and Panton question the procedures, results, and implications of our study (LH) of the forward-pricing ability of the hog futures market. Pasour contends "the finding of inefficiency on the part of live-hog futures traders is not warranted because [the model] does not take into account the costs and benefits of additional information to individual traders." Panton argues the efficient market hypothesis (EMH) does not suggest that "futures prices in an efficient market can be relied upon to reflect subsequent spot prices accurately." In our reply, we will discuss the benefit/cost issue, the criteria for testing market efficiency and the EMH, and the use of our model as a norm.

Cost and Benefits

Specific costs and benefits for acquiring additional information are not included explicitly in our model. We will examine each of them here to ascertain the seriousness of the omission and, thereby, the reliability of our tests. Both the costs and benefits are most likely perceived rather than carefully calculated, and they, especially costs, will differ for new or potential traders as opposed to existing traders.[1] The costs for acquiring information to trade successfully for a new trader can be substantial if the trader is going to make decisions without outside advice. The level of costs depends upon the initial base of knowledge. It is well rumored that in the futures markets a high proportion of the traders trade once or twice, lose some money, and never trade again. Certainly to them, the perceived costs exceed the perceived benefits, but it would be hard to argue that such traders operating on their own have a large impact on the forward-pricing ability of a market.

Alternatively, the inexperienced trader can turn investment money over to a commodity fund or follow the strict advice of an account executive, and the cost of additional information to this individual may approximate the cost of commissions. The burden for acquiring information and retaining the customer through successful trades lies with the brokerage house. It is here that we want to concentrate our attention. The people who have the greatest influence on price information are brokerage houses, consulting firms, commodity clubs, professional speculators, active public speculators, and commercial firms, either directly or indirectly. Although we discussed in LH alternatives for potentially improving forward-pricing efficiency, it is the above listed traders who must be evaluated *ex post* on their utilization of available information.

In building our econometric model, we deliberately kept it from being complex by utilizing just one supply equation and one demand equation. We incorporated only five economic variables, hog slaughter, sow farrowings, hog/corn price ratio, income, and the price of hogs, data which are readily available in free government publications. It is difficult to imagine any existing trader in the market with even modest experience not examining all or some of these variables before making a decision. The cost of acquiring them is extremely low. The real cost may come in assimilating the information in such a manner to obtain appropriate implications. Nevertheless, the marginal costs for additional information for existing traders in futures markets are low. With our model, it is not even necessary to gather information to "anticipate" government releases. However, the level of additional costs is important only relative to the marginal benefits.[2]

There are many potential benefits from acquiring more information relative to futures markets, but we will concentrate on just one, speculative profits. In LH we state, ". . . using the econometric model to indicate the direction of futures market price changes, and utilizing the naive trading strategy of buy-and-hold if the predicted price exceeds the futures price (if opposite, sell-and-hold), substantial trading profits could have been generated between 1971 and 1978 in the hog futures market" (p. 487). We did not consider the details sufficiently relevant to incorporate in the original paper, but they need reporting here. In fact, we now have additional results through 1979, giving us sixty-two different contracts for investment simulation. Using the above naive strategy and making trading decisions

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The authors wish to thank Philip Garcia and Larry Martin for comments on an earlier draft, but absolve them of any responsibility.

[1] Pasour quotes Stigler on this latter point.

[2] It is not clear whether Pasour includes relative risks in his benefit/cost model.

A Semi-Strong Form Evaluation of the Efficiency of the Hog Futures Market: Comment

Don B. Panton

In a recent issue of this *Journal* (August 1979) Leuthold and Hartmann (LH) offered a methodology which was directed at evaluating the semi-strong form efficiency of the hog futures market. The authors employed an econometric model to forecast cash hog prices at contract maturity. Because the econometric model was observed to have greater forecasting merit than did the respective futures prices, the authors concluded that the hog futures market is semi-strong inefficient.

As LH observe, an efficient market has been defined by Fama as one in which prices fully reflect all available information. For any test of the efficient markets hypothesis (EMH) to be operational, one must identify relevant explanatory variables and the specific nature of the linking relation. Thus, any test of the EMH is, at the same time, a test of the postulated model. The LH model has little, if any, basis in theory; therefore, the model itself would be a prime suspect in any test of market efficiency.

LH state, "The hog futures prices cannot consistently be relied upon to reflect accurately subsequent spot prices, and thereby the market is not considered efficient." LH have destroyed a straw man; the EMH does not say, imply, or hint that futures prices in an efficient market can be relied upon to reflect subsequent cash prices accurately. Instead, the EMH does state that known information is impounded in current price, so that all desirable characteristics of the investment (usually expected return) are in equilibrium with all undesirable characteristics of the investment (usually covariance of return with that of the market portfolio).

Unless returns resulting from the use of a pricing model like that of LH are found to be in excess of returns justified by risk, the EMH cannot reasonably be rejected. Thus, for an appropriate test of market efficiency, it would be necessary to determine whether returns received from trading based on the econometric model exceed normal returns adjusted for risk. As Rendleman and Carabini (p. 913) state, "To determine the extent of the (Treasury Bill Futures) market, it is necessary to assess the significance of the quasi-arbitrage returns that could have been earned." If risk cannot be shown to vanish through arbitrage or diversification activities, one must compare realized returns to normal returns appropriately adjusted via a general equilibrium model. LH have not shown that their pricing model systematically identifies opportunities for excess returns; therefore, no justification exists for their statement: "We find that on occasion the econometric model provides more accurate forecasts of subsequent prices than does the futures market, implying that objectionable inaccuracies exist in the futures market. This means that the live-hog futures market is not performing efficiently. . . ."

Granted, a researcher may be dissatisfied with the applicability of currently available equilibrium models (e.g., the capital asset-pricing model) to futures trading. The point is, however, that the onus is upon the researcher to provide such a model if he proposes to determine whether a financial market is operating efficiently. An equilibrium model is a prerequisite to any empirical study of the EMH and risky markets.

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References

Fama, E. F. "Efficient Capital Markets: A Review of Theory and Empirical Work." *J. Finance* 25(1970):383–417.

Leuthold, R. M., and P. A. Hartmann. "A Semi-Strong Form Evaluation of the Efficiency of the Hog Futures Market." *Amer. J. Agr. Econ.* 61(1979):482–89.

Rendleman, R. J., and C. E. Carabini. "The Efficiency of the Treasury Bill Futures Market." *J. Finance* 34(1979):895–914.

Conclusions

Finally, and closely related, econometric models need not be viewed as an alternative to the futures market but rather (as the authors suggest) as a way to increase the forward-pricing accuracy of the futures market. LH find that for some time periods their econometric model provides more accurate forecasts of subsequent prices than does the futures market and on this basis conclude that the hog futures market is not efficient. In order to prove market inefficiency in the LH approach, it is necessary to find only one case in which some other model predicts better. Hence, to prove the inefficiency of the LH model, one presumably would need to find only one case where the futures market (or another econometric model) provides more accurate forecasts. It appears, therefore, that the econometric model developed by LH does not meet the efficiency criterion by which they judge the live-hog futures market, i.e., it does not "consistently and accurately" reflect subsequent spot prices. Much work remains to be done on this problem of market efficiency, but when it is realized that neither real world markets nor econometric models can consistently and accurately predict the future, no work is required to reject the criterion that an efficient futures market must accurately and consistently reflect subsequent cash prices.

The conclusion that better informed traders could improve the forward pricing accuracy of the futures market is unassailable and, if information were not scarce, it presumably would not be difficult to identify inefficient trading activities. Under real world conditions of uncertainty, however, an economically meaningful criterion of an efficient trader (or an efficient market) appears to be one with an "appropriate amount" of information and meaningful tests of efficiency are much more difficult. The Alchian "survival criterion" would seem to be the most appropriate test of whether any econometric model can be used to increase the accuracy of futures markets. In the futures market as well as the kitchen, "the proof of the pudding is in the eating."

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References

Alchian, A. A. "Uncertainty, Evolution and Economic Theory." *J. Polit. Econ.* 58(1950):211–21.

Demsetz, Harold. "Information and Efficiency: Another Viewpoint." *J. Law and Econ.* 12(1969):1–22.

Fama, E. F. "Efficient Capital Markets: A Review of Theory and Empirical Work." *J. Finance* 25(1970):383–417.

Leuthold, R. M., and Peter A. Hartmann. "A Semi-Strong Form Evaluation of the Efficiency of the Hog Futures Market." *Amer. J. Agr. Econ.* 61 (1979): 482–88.

Pasour, E. C., Jr., and J. Bruce Bullock. "Implications of Uncertainty for the Measurement of Efficiency." *Amer. J. Agr. Econ.* 57(1975):335–39.

Stigler, George J. "Imperfections in the Capital Market." *J. Polit. Econ.* 75(1967):287–92.

———. "The Economics of Information." *J. Polit. Econ.* 69(1961):213–25.

———. "The Xistence of X-Efficiency." *Amer. Econ. Rev.* 66(1976):213–16.

trader. Expected benefits of acquiring knowledge about the futures market, for example, likely would be much different for a farmer nearing retirement (or planning to change careers) than for a farmer who anticipates that he will produce hogs for another twenty-five years. This suggests that it is economic for traders (and other decision makers) to devote different amounts of time (and effort) in acquiring knowledge (Stigler 1976, p. 215). Whether it is rational for a particular trader to acquire additional information hinges on a comparison of the expected benefits and costs.

Traders cannot rationally be expected to base their decisions on all publicly available information. As Stigler (1967 p. 291) states, "information costs are the costs of transportation from ignorance to omniscience and seldom can a trader afford to take the entire trip." It does not follow then that the level of knowledge held by current traders is inefficient unless the expected benefits of additional information exceed the costs. The identification and measurement of entrepreneurial inefficiency requires information concerning both the trader's knowledge and the optimal amount of knowledge that the decision maker should possess. The problem of identifying inefficiency on the part of market traders does not appear to be alleviated by defining an efficient market in terms of "necessary inaccuracy."[4] While imperfect knowledge is indeed a necessary fact of life, the amount of knowledge acquired by any trader, as suggested above, will hinge on the costs and benefits as he perceives them to be. The failure of market participants to become better informed suggests that the expected costs exceed the benefits.

A problem arises in identifying inefficient trading behavior under real world conditions because of the inability to define meaningfully the "optimal" situation in a world of uncertainty, imperfect knowledge, and costly information. Economic efficiency inevitably involves valuation by the decision maker. A situation would appear to be efficient when the entrepreneur has no preferred alternative, given the circumstances (Pasour and Bullock). Thus, to identify and measure inefficiency, the defined efficiency goal must correspond to that of the decision maker and it must account for uncertainty, costly information, and other aspects of the operating environment in which decisions are made.[5] Use of a norm which fails to take account of this environment is almost certain to lead to an incorrect assessment of the efficiency of real world economic activity.

Second, the fact that there is generally a difference between hog futures prices and subsequent spot prices does not imply market inefficiency.[6] Speculative error does not imply "objectionable inaccuracy." That is, the fact that futures market traders are sometimes "poor speculators" cannot appropriately be taken as an indication of inefficiency but suggests only that decision makers would make "better choices" if imperfect knowledge were not a fact of life. Because imperfect knowledge and uncertainty are facts of life and cannot be reduced at zero cost, then a truly efficient futures market appears to be different from the ideal norm assumed by LH, *viz,* that futures prices must consistently and accurately reflect subsequent spot prices. In dealing with the future, ignorance is unavoidable although an investment in knowledge can reduce its effects. However, even if it were possible to eliminate all the effects of ignorance, it would be uneconomic to do so.[7] Thus, the marginal rule applies to information just as it does to all other scarce resources. The profit-maximizing decision maker will attempt to acquire additional information only as long as the expected benefits exceed the costs.

If consistently accurate prediction of future price is the norm by which efficiency is judged, no market or econometric model will be efficient in a world characterized by change and uncertainty. This view of public policy, which represents the relevant choice as between an ideal norm and an existing imperfect institutional arrangement, has been characterized by Demsetz as the nirvana approach. In this approach, "those who adopt the nirvana viewpoint seek to discover discrepancies between the ideal and the real and, if discrepancies are found, they deduce that the real is inefficient" (Demsetz, p. 1).

The conclusion that the futures market is inefficient implies that an attainable alternative is better able to cope with price uncertainty. But, as the nirvana approach suggests, all institutional arrangements are imperfect when measured against an idealized norm. Whether the current hog futures market is inefficient hinges on whether there is an alternative institutional arrangement better able to cope with future price uncertainty. Moreover, any such alternative which improves the accuracy of forecasts represents an increase in efficiency only if the benefits exceed the costs.

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[4] "An efficient market contains only necessary inaccuracy; price changes are due to new information. Any error beyond that is objectionable inaccuracy often termed as speculative error, and likely results from bad judgment of traders or from noncompetitive market situations" (Leuthold and Hartmann, p. 483).

[5] Alchian proposes firm survival as a criterion for evaluating entrepreneurial success. This approach avoids the problem of attempts to measure costs and returns which motivate entrepreneurial choice.

[6] "The hog futures price cannot consistently be relied upon to reflect accurately subsequent spot prices, and thereby the market is not considered efficient" (Leuthold and Hartmann, p. 488). If the econometric model is accepted as the performance norm, what does one conclude about the level of trader information for those time periods when the futures market provides a more accurate forecast than the econometric model? Do traders have too much information during these periods?

[7] "Ignorance is like subzero weather: by a sufficient expenditure its effects upon people can be kept within tolerable or even comfortable bounds, but it would be wholly uneconomic entirely to eliminate all its effects" (Stigler 1961, p. 224).

A Semi-Strong Form Evaluation of the Efficiency of the Hog Futures Market: Comment

E. C. Pasour, Jr.

In a recent study, Leuthold and Hartmann (hereafter LH) conclude that the live-hog futures market is not efficient. It is the purpose of this note to show that the findings of the LH study do not imply that the hog futures market is inefficient in an economically meaningful sense. The primary issue concerns the definition of efficiency. Although the "efficient market" criterion of the finance literature is the stated performance criterion in the LH study, the following analysis is directed specifically toward the alleged inefficiency of the hog futures market as identified by LH.[1] The major thrust of this comment is that the finding of inefficiency on the part of live-hog futures traders is not warranted because it does not take into account the costs and benefits of additional information to individual traders.

The comment is organized as follows. First, the criterion of market efficiency, procedure, and inefficiency findings of the LH study are briefly summarized. Second, the conclusion of the LH study that market traders have too little information in some years is challenged because the approach used does not consider the costs and benefits of information from the standpoint of individual traders. Third, the significance of the development of an econometric model with superior predictive power is briefly explored.

Approach of LH Study

Market efficiency in the LH study hinges on the extent to which the market utilizes all publicly available information.[2] The basic procedure and conclusions of the LH study are described in the following passage:

> An econometric model designed to forecast hog prices reflecting available public information is developed to act as the norm against which futures prices can be compared. Using alternative methods of evaluation, we find that on occasion the econometric model provides more accurate forecasts of subsequent prices than does the futures market, implying that objectionable inaccuracies exist in the futures market. This means that the live-hog futures market is not performing efficiently, presumably because of the markets inability to reflect fully all information. (p. 483)

In any time period when the econometric model provides a more accurate forecast, the futures market is assumed not to reflect fully available information and is held to be inefficient.[3] The study finds that traders have too little information in some years and that "more or better informed traders could improve the forward pricing accuracy of the futures market" (p. 487). Consequently, "educational programs designed to inform producers of the market's benefits" might be justified to "encourage a well-informed group of traders into the market" (p. 488).

The following section demonstrates the problems in identifying inefficient entrepreneurial behavior on the part of market traders when uncertainty and information costs are taken into account.

Efficiency and Information Costs

First, consider the problem of determining whether individual traders have too little information. Trading in the futures market requires an investment in knowledge. Whether traders would benefit from additional information hinges on the costs and benefits of such information. Moreover, the costs and returns of acquiring information vary from trader to

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[1] No attempt in this paper is made to compare the "efficient market" approach of the LH study with that of related studies in the finance area. Hence, it is not clear to what extent the criticisms made here of the "efficient market" approach in the LH study apply generally to "efficient market" studies.

[2] "If prices reflect all publicly available information as it is released, the market is said to be semi-strong efficient" (Leuthold and Hartmann, p. 483). The semi-strong form test of the efficiency of the hog futures market in the LH study is purported to be the same as that used in the finance literature, i.e., semi-strong form tests of efficient market models are concerned with whether current prices "fully reflect" all "obviously publicly available information" such as stock splits, announcements of financial reports by firms, or new security issues (Fama, p. 404). In reality, it is doubtful that predictions from an econometric model based on publicly available information can also legitimately be considered "obviously publicly available."

[3] "Using an econometric forecasting model as a performance norm, the futures market by comparison has not at all times fully reflected the available information. This has allowed us to observe the presence of objectionable inaccuracies" (Leuthold and Hartmann, p. 488).

seller's sunk costs. The seller may be willing to accept a feeder sale price below that required to cover all sunk costs if he perceives that this price is the most buyers will be willing to pay. Alternatively, short-run seller reservation prices could more than cover total production costs in years of strong buyer demand.

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References

Buccola, S. T., and D. L. Jessee. "A U.S. Regional Model of Feeder Steer-Heifer Price Differentials." *S. J. Agr. Econ.* 11(1979):61–65.

Chicago Mercantile Exchange. *Chicago Mercantile Exchange Yearbook.* Market News Department, annual issues.

Crickenberger, R. G., and J. R. Black. *Influence of Frame Size on Performance and Economic Considerations of Feedlot Cattle.* Michigan State University Agr. Exp. Sta. Res. Bull. No. 318, 1976.

James, J. B., and D. E. Farris. *Factors Affecting Price Differences of Cattle in the Southwest.* Texas Agr. Exp. Sta. Bull. B-1106, 1971.

Maki, W. R. "Decomposition of the Beef and Pork Cycles." *J. Farm Econ.* 44(1962):731–43.

National Academy of Sciences. *Nutrient Requirements of Beef Cattle,* 5th ed. Washington, D.C., 1976.

Smith, H. *Meteorological Drought Summary in Virginia (1929–1977).* Richmond, Va.: U.S. Department of Commerce, National Weather Service, 1977.

U.S. Department of Agriculture. *Livestock and Meat Situation.* Washington, D.C.: Economics, Statistics, and Cooperatives Service, monthly issues.

$1.36 per hundredweight, but average 500-pound Choice feeder prices rose $0.10 per hundredweight more than average 600-pound Choice feeder prices. The coefficients of r suggest that rising corn prices not only diminish average Choice feeder prices but also decrease relative premiums on lightweight feeders. Every $1.00 per bushel increase in corn prices served to decrease overall average Choice feeder prices by $8.33 per hundredweight; at the same time, average 500-pound Choice feeder prices fell $1.11 per hundredweight more than average 600-pound Choice feeder prices. Coefficients of the Palmer soil moisture index and cattle inventory change may be interpreted similarly.

Coefficients of the sex dummy variables in each equation of table 3 (sex = 0 if a steer and 1 if a heifer) indicate that Choice heifers brought lower average prices than did Choice steers, and that dollar discounts on heavyweight over lightweight heifers were less than dollar discounts on heavyweight over lightweight steers. In 1977 dollars, Choice heifer prices averaged $46.55 per hundredweight and decreased an average $1.19 per hundredweight for every 100-pound increase in market weight. Choice steer prices averaged $54.68 per hundredweight and decreased an average $2.74 per hundredweight for every 100-pound weight increase.

A notable result was that interaction terms involving the sex variable and other explanatory variables were statistically significant in the model in which the dependent variable was average feeder price, but they were not significant in the model in which the dependent variable was the rate of feeder price change with respect to weight. Thus, corn price rises increase market price differentials between feeder steers and heifers at average weights; but they do not appear to affect the difference between steers and heifers in the rate at which market price changes with weight. In other words, buyers and sellers in the feeder markets analyzed behave as though expressions (ii) and (iv) in table 2 were negligible in magnitude.

Conclusions

The above results suggest that break-even analysis can be used successfully to clarify our understanding of market price differentials between different lots of feeder cattle. In general, the same variables that affect feeder price levels themselves also affect the price differentials observed between different classes of feeder cattle. Expected slaughter cattle prices, feed prices, soil moisture conditions, and rates of cattle inventory changes affect both average feeder prices and the rates at which feeder prices change with weight, although the directions of effect are opposite in sign.

The simulation-derived impacts of slaughter cattle and corn prices on feeder price-weight slopes agreed in sign with, but were considerably higher than, those estimated empirically. At a typical steer weight of 600 pounds, the simulated impact of an expected slaughter price increase on the rate at which buyer break-even feeder price changes with weight was three times that evidenced in the statistical results. One explanation for this discrepancy is that buyers are skeptical of the accuracy with which current slaughter cattle futures prices predict subsequent cash prices, and so react cautiously to changes in futures price levels.

Even in observed auction market transactions, buyer and seller profitability factors such as slaughter cattle price expectations have relatively stronger effects on feeder price-weight slopes than on average feeder prices. At sample mean variable values in table 3, a 1% rise in expected slaughter cattle price raises average feeder price by 1.36%, but it increases the premium on lightweight over heavyweight cattle (that is, the price-weight slope) by 2.62%. Similarly, a 1% increase in the corn price decreases average feeder prices by 0.4% but decreases premiums on lightweight over heavyweight cattle by 1.37%.

The estimated mean price-weight relationships, and impacts of buyer and seller profitability factors on these relationships, shown in table 3 represent linear approximations only and hence are strictly applicable only in the average weight ranges for steers and heifers (550–750 pounds and 450–600 pounds, respectively). Extension of the empirical analysis to nonlinear relationships can be approached by dividing the relationships into linear segments according to weight class, or by analyzing the second and higher derivatives of price-weight functions. Statistical results not reported in detail here did show that, among steers, market price-weight lines are generally convex from below, meaning that prices decrease at a decreasing rate as weight rises. Among heifers, market price-weight lines are usually slightly concave from below, if only because heifer prices often rise between the 300- and 400-pound weight levels before decreasing again. Only in some regression specifications slaughter cattle prices were found to affect significantly the curvature of feeder price-weight relationships. For example, increases in expected slaughter steer prices often were associated with increases in the rate at which feeder steer price-weight slopes diminish as weight rises.

A clear distinction should be made between the price-weight relationships observed at feeder cattle markets and the changes in per hundredweight price that occur when animals gain weight in the feedlot. High concentrate feeding may result in increasing an animal's grade as well as its weight, and price-weight trade-offs among slaughter cattle differ from those among feeder cattle.

Finally, it should be emphasized that break-even prices as defined here may not be used reliably to estimate short-run buyer or seller reservation prices. For example, in any particular sale period, weaned calf purchase value represents part of a

statistical analysis of actual feeder cattle markets. In long-run, perfectly competitive equilibrium, buyer and seller break-even price-weight relationships for a specific feeder type, and for a given time and place, are identical to one another and to market prices. Although due in part to the beef price-inventory cycle, this equilibrium is constantly shifting, and hence never achieved. Theoretically hypothesized signs should predominate if a sufficiently long time frame is observed. In order to provide statistical tests of the relationships developed above, twenty years of Virginia state-graded feeder cattle transaction data, involving 133,907 sale lots, were stratified by year, sex (steer and heifer), and season (spring and fall); and sale prices in each stratum were regressed against corresponding animal and market characteristics. The former characteristics included weight, breed, grade, and age; the latter included sales size, lot size, auction sale order, market location, and day. Interaction terms between weight and grade were used to isolate differences between feeder cattle grades in market price-weight relations. Weight variables themselves were employed alternately in linear and nonlinear form.

For each functional form fitted, this process generated eighty regression coefficients for each of the animal and market characteristics listed. For example, the eighty coefficients of the linear weight variables constituted a linear estimate for each year, sex, and season, of the marginal impact of feeder weight on feeder market price. These estimated linear price-weight slopes for Choice steers and heifers were then regressed against the revenue and cost factors hypothesized by the above conceptual model to affect them. Current live cattle futures prices (P) were used to represent buyers' expected slaughter prices and current Chicago No. 2 yellow corn prices (r) were used to represent feed price movements. The Palmer index of northern Virginia soil moisture conditions (PI) was included to represent changes in stocker grazing costs. Because the index varies directly with soil moisture, it should, with the exception of flood years, vary directly with pasture quality and inversely with grazing or hay costs.[4] Finally, annual rates of change in 1 January all-cattle inventories (ΔINV) were utilized to account for the effect of cattle inventory adjustments on feeder price formation.[5] Residual sex, season, and year effects also were tested, but only sex effects were statistically significant. All price and slope variables were inflated to a fall 1977 basis.

Results of the regression are shown in the Price-Weight Slope row of table 3. For purposes of comparison, average feeder steer and heifer prices in each year and season also are regressed against the above revenue and cost factors and the results given in the Average Price row of table 3. Taken together, these equations provide an estimate of the marginal impact of each revenue or cost factor on both average feeder price and the average rate of change of feeder price with respect to weight. For example, the coefficients for P indicate that rising slaughter steer prices not only increase average feeder prices but also increase relative premiums on lightweight feeders. For every \$1.00 per hundredweight increase in expected slaughter steer price, the overall average Choice feeder price rose

[4] Live cattle futures prices were, for spring observations on the dependent variable, mid-April quotes of October 1050–1200-pound Choice steer contracts and, for fall observations, mid-October quotes of April 1050–1200-pound Choice steer contracts (Chicago Mercantile Exchange). For years prior to the inception of a cattle futures market (1967), spring average and fall average cash prices of 900–1100-pound Choice Omaha slaughter steers were utilized instead. Corn prices used were, for spring observations, unweighted March-April-May averages of Chicago No. 2 yellow cash prices and, for fall observations, unweighted September-October-November averages (USDA). Palmer index data were taken from Smith.

[5] It is expected that rising cattle inventories are associated with more negative or less positive price-weight slopes since light calf prices are bid up relative to heavy stockers in the anticipation of higher prices for both feeder sexes. ΔINV is $INV_t - INV_{t-1}$, where t refers to the 1 January inventory following the time period of regression; this provides the best estimate we have of inventory changes the preceding year.

Table 3. Determinants of Feeder Cattle Price-Weight Slopes and of Average Feeder Cattle Prices, Virginia State-Graded Auction Sales, 1958–77.

	P	r	PI	ΔINV	SEX	$INTERCEPT$
Price-weight Slope[a]	−0.1008 (−6.41)	1.1086 (6.33)	−0.1207 (−2.62)	−0.0065 (−3.43)	1.5561 (9.17)	−0.1900 (−0.24)
Average Price[b]	1.3658 (15.33)	−8.3148 (−8.37)	0.9654 (3.70)	0.0065 (0.61)	−8.1268 (−8.45)	4.9697 (1.12)
Variable unit	\$/cwt	\$/bu	−5 dry to +5 wet	1000 head	steer = 0 heifer = 1	
Variable mean value	51.13	2.42	−.056	7.325	.5	

[a] Marginal impact of indicated variable on the change in Choice feeder cattle price caused by a 100-pound weight increase (price-weight slope). Dependent variable mean: \$−1.9646/cwt per hundredweight increase. Observations: 80. R^2 = .733.

[b] Marginal impact of indicated variable on average Choice feeder cattle price. Dependent variable mean: \$50.62/cwt. Observations: 80. R^2 = .848.

Table 2. Simulated Break-Even Feeder Cattle Price Relations, Buyer and Seller, 1977

	Purchase Weight (cwt)	Break-Even Price ($/cwt)	Slope of Price-Weight Relation[a] ($/cwt/cwt)	Impact of Feed Price Change on Slope of Price-Weight Relation[b]
			Buyer (Feedlot)	
Steers	5.00	47.69	−4.98	.351
	6.00	43.76	−3.07	.258
	7.00	41.31	−1.91	.202
	8.00	39.79	−1.17	.166
	9.00	38.90	− .65	.141
Heifers	4.00	44.22	−5.55	.425
	5.00	40.09	−3.00	.292
	6.00	37.84	−1.62	.220
	7.00	36.68	− .78	.176
	8.00	36.18	− .24	.148
			Seller (Stocker)	
Steers	5.00	43.12	.240	.025
	6.00	43.65	.759	.019
	7.00	44.58	1.072	.016
	8.00	45.76	1.275	.014
	9.00	47.10	1.414	.013
Heifers	4.00	33.00	4.387	.033
	5.00	37.08	3.834	.024
	6.00	40.75	3.534	.021
	7.00	44.19	3.353	.018
	8.00	47.48	3.236	.016

[a] Marginal rate at which price changes, in $/cwt per 100-lb. weight increase, as evaluated at each weight shown.
[b] Marginal rate of increase in the price-weight slope, in $/cwt per 100-lb. weight increase, caused by a .10¢/Mcal. *ME* increase in feed price *r* or *s*. (If corn were the entire ration, a .10¢/Mcal. *ME* price rise would result from a 9.4¢/bu. increase in the corn price.)

over heavyweight cattle.[2] Interestingly, weight-by-weight comparison of steer and heifer values in the buyer's portion of column (4) suggests that feed price rises serve to increase algebraically a steer's break-even price-weight slope more than they do a heifer's. Because, in years in which buyers' break-even feeder prices decline with weight, break-even steer prices normally decline much more rapidly than they do for heifers, the implication is that increasing feed prices should serve to diminish the difference between steers and heifers in the rate at which price declines with added weight.[3]

Empirical Analysis

Simulations such as these not only may provide pricing guidance to individual firm operators, but also may represent a source of hypotheses for

[2] Entries in the seller portion of column (4), table 2, are positively biased because reliable estimates of the effect of grazing costs on weaned calf prices, $p^*_s(s, D)$, were not obtained.

[3] Despite this, there is good theoretical reason and statistical evidence that increasing feed prices tend to increase premiums of steer prices over heifer prices at any given weight (Buccola and Jessee).

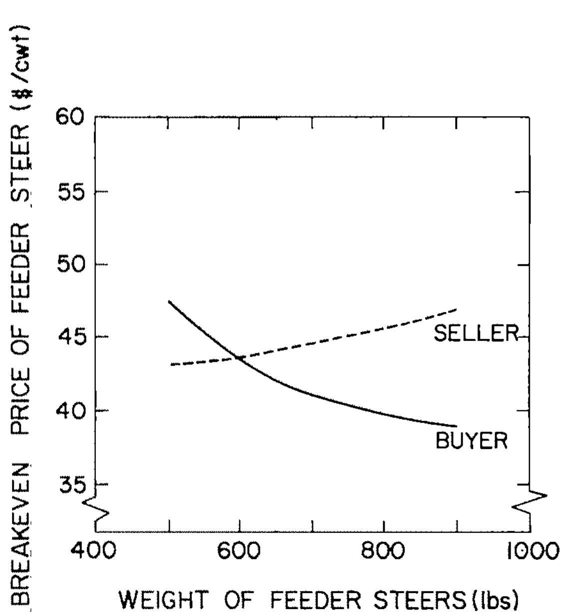

Figure 1. Simulated break-even price-weight lines for feeder steers, buyer and seller, 1977

Table 1. Impact of Feed Prices and Feeder Cattle Characteristics on Rate At Which Break-Even Feeder Prices Change with Weight

	(a) Impact of Feed Price Change on Break-Even Feeder Price-Weight Slope[a]	(b) Effect of Feeder Characteristics on Relationship in Column (a)
Buyer	(i) $f(w,D\|GF,W)W/w^2 - f_w(w,D\|GF,W)\ (W/w - \ )$	(ii) $f_d(w,D\|GF,W)W/w^2 - f_{w,d}(w,D\|GF,W)\ (W/w - 1)$
Seller	(iii) $-p^*_s(s,D)w^*/w^2 + i(w,D\|GP,w^*)w^*/w^2 + i_w(w,D\|w^*)\ (1-w^*/w)$	(iv) $-p^*_{s,d}(s,D)w^*/w^2 + i_d(w,D\|GP,w^*)w^*/w^2 + i_{w,d}(w,D\|GP,w^*)\ (1 - w^*/w)$

[a] In the notation employed in this table, $f_d(w,D|GF,W)$ represents the difference between two classes of animals in average feed efficiency, given a constant purchase weight. Term $f_{w,d}(w,D|GF,W)$ represents the difference between the two classes of animals in the rate of average feed efficiency loss as purchase weight rises. Terms $i_d(w,D|GP,w^*)$ and $i_{w,d}$ $(w,D|GP,w^*)$ are defined in a parallel way for grazing efficiency. Other notation is as defined and used previously.

values, leave indeterminate whether rising feed prices increase or decrease the difference between these two classes of cattle in the rate at which break-even prices change with purchase weight.

Simulation of Price Differentials

Thus, signs and magnitudes of expressions (3), (4), and the terms in table 1 require an understanding of the feed conversion functions f, i; daily-basis nonfeed cost functions g, j; per-head-basis nonfeed costs $h(D)$, $k(D)$; slaughter and weaning weights W, w^*; weaned calf price p^* and expected slaughter-weight prices P; daily gains GF and GP; and feed prices r and s. To gain better insight into these relationships and their changes over time, a hypothetical buyer's and hypothetical seller's break-even feeder prices were simulated at selected weights and, for both steers and heifers, for each fall sale during the period 1968–77.

Parameters, feed requirement functions, and cost functions employed in the simulation corresponded to a Virginia stocker operator and Corn Belt feedlot operator. Estimates of feed efficiency functions f and i were derived from National Research Council data (National Academy of Sciences, pp. 22–25). In these estimates, the following were assumed: GF = 2.4 pounds per day (steers) and 2.0 pounds per day (heifers); GP = 1.0 pounds per day (steers) and 0.8 pounds per day (heifers); W = 1,050 pounds (steers) and 840 pounds (heifers), both Low Choice; w^* = 450 pounds (steers) and 400 pounds (heifers). Daily-basis nonfeed feedlot cost function g (machinery, labor, death loss, depreciation, interest) and per-head-basis feedlot cost $h(D)$ (hauling and marketing, veterinary) were adapted from Crickenberger and Black (1976, pp. 57–71). The feed ration employed consisted of 53% corn silage, 44% cracked corn, and 3% soybean meal, ME basis. Feed and slaughter cattle price expectations were represented by August through October price averages (USDA).

In eight of the ten years simulated, the feeder buyer's break-even purchase prices for both steers and heifers declined with increases in purchase weight; that is, equation (3) was negative. The two fall seasons for which break-even prices increased with weight (1974 and 1976) were the only falls in which slaughter cattle/corn price ratios fell below 17.0; this had the effect of diminishing the negative first term in (3) relative to the positive second term. Third and subsequent terms in (3) were less important, though not negligible, in magnitude.

On the seller side, break-even steer prices declined with weight during every year except 1976 and 1977, implying that the first and last terms in (4) were normally greater in absolute value than all other terms combined. For heifers, however, break-even sale prices increased with weight in four of the ten years studied and were nearly invariant with respect to weight in two additional years. The tendency of heifer break-even sale prices to increase with weight owes partly to the greater grazing nutrient requirements per pound gain in heifers than in steers, and hence the greater relative importance to heifers of the second term in (4). Third and subsequent terms in (4) were less important in magnitude.

Simulation results for the year 1977 are shown in table 2. The buyer's and seller's break-even feeder steer price-weight relations for 1977 are illustrated in figure 1. Column (4) of table 2 provides data for evaluating the expressions in table 1 which, lacking feed price or feed cost coefficients, are invariant from year to year. Simulated values of expression (i), table 1, are given in the buyer portion of column (4), and simulated values of expression (iii) are given in the seller portion of column (4). Simulated values of expressions (ii) and (iv) are evaluated for the sex characteristic by subtracting steer entries from heifer entries at constant weights, for example by subtracting .292 from .351 at the 500-pound market weight level.

The fact that all entries in column (4) of table 2 are positive signifies that increasing feed prices should diminish the relative premiums that buyers would offer, and sellers demand, for lightweight

hand side of (1), then, consists, respectively, of expected per-head slaughter animal revenue, feed cost, daily-basis nonfeed cost, per-head-basis nonfeed cost, and feeder animal cost.

Similarly, consider a farmer who sells a feeder animal which he has purchased (from himself or another) as a weaned calf and grazed for a variable period. Defining w^* as the weight of calf at weaning, in hundredweight; s as price or value of pasture or hay nutrients, in \$/Mcal ME; GP as average daily gain on pasture, in hundredweight per day; $i(w,D|GP,w^*)$ as average efficiency of grass/gain conversion, in Mcal/cwt gain; $j(w,D|w^*)$ as average daily-basis nonpasture cost of animal maintenance on farm, in dollars per day; $k(D)$ as per head cost of animal maintenance on farm, in dollars; and $p^*(s,D)$ as price of calf at weaning, in dollars per hundredweight, the per head profits (π_s) faced by the feeder cattle seller are

(2)
$$\pi_s = pw - p^*(s,D)w^* - s(w - w^*)i(w,D|GP,w^*) - (w - w^*)[j(w,D|w^*)/GP] - k(D).$$

The right-hand side of (2) consists respectively of per-head feeder animal revenue, weaned calf cost, pasture cost, daily-basis nonpasture cost, and per-head-basis nonpasture cost.

The buyer's and seller's break-even prices for a lot of feeder cattle are found by setting (1) and (2) equal to zero and solving each for per hundredweight feeder price p. The impact of a marginal change in feeder sale weight, for example, on these break-even prices can then be determined by differentiating the resulting equations with respect to w. Defining the buyer's break-even price for a particular sale lot as p^b and the seller's break-even price for this lot as p^s, and denoting first derivatives with respect to weight by w subscripts, the impacts are

(3)
$$\begin{aligned} dp^b/dw = {} & -P(W,D)W/w^2 + rf(w,D|GF,W)W/w^2 \\ & - rf_w(w,D|GF,W)(W/w - 1) \\ & + [g(w,D|W)/GF]W/w^2 \\ & - [g_w(w,D|W)/GF](W/w - 1) \\ & + h(D)/w^2, \end{aligned}$$

(4)
$$\begin{aligned} dp^s/dw = {} & -p^*(s,D)w^*/w^2 + si(w,D|GP,w^*)w^*/w^2 \\ & + si_w(w,D|GP,w^*)(1 - w^*/w) \\ & + [j(w,D|w^*)/GP]w^*/w^2 \\ & + [j_w(w,D|w^*)/GP](1 - w^*/w) \\ & - k(D)/w^2. \end{aligned}$$

In equation (3), one may assume that slopes $f_w(w,D|GF,W)$ and $g_w(w,D|W)$, respectively representing marginal losses in average feed efficiency and marginal increases in average daily nonfeed costs as feeder sale weight rises, are positive (National Academy of Sciences). Hence, the first right-hand-side term in (3) is negative and the rest alternate in sign; the net sign and value of the entire expression depend upon the relative absolute values of these terms. The sign of equation (4) is similarly indeterminate: the first and last right-hand-side terms are negative, but the others are nonnegative since $i_w(w,D|GP,w^*)$, like $f_w(w,D|GF,W)$, is positive, and $j_w(w,D|w^*)$ is probably close to zero.

Expected slaughter cattle prices and current feed and pasture costs are the principal factors affecting the rate at which a buyer's or seller's per hundredweight break-even prices rise or fall with feeder animal sale weight. The degree to which slaughter cattle or feed prices affect this rate depends in turn on the characteristics of the feeder animal considered: its grade, breed, sex, frame size, and age. This may be seen by first differentiating equations (3) and (4) with respect to per hundredweight slaughter cattle price P and feed or pasture nutrient prices r or s, then differentiating the resulting equations with respect to feeder animal description D. Slaughter cattle prices apply, of course, only to the buyer's profit function (3). The derivative of (3) with respect to P, that is W/w^2, is negative, meaning that rising slaughter cattle price expectations cause buyers to bid up per hundredweight prices of lightweight feeders relative to heavyweight feeders. Derivatives of (3) and (4) with respect to feed prices present a more complex picture and are shown in table 1.

Expression (i) in table 1 represents the effect of a unit change in feed price on the buyer's price-weight slope, the rate at which the buyer's break-even feeder price changes with feeder purchase weight. Expression (ii) simply shows the difference we expect in this effect between two animals with distinct sex, grade, or other characteristics. Expressions (iii) and (iv) are defined similarly for the seller of feeder calves. Like the price-weight slopes in equations (3) and (4), each of the expressions in table 1 is indeterminate in sign without information on the feed efficiency functions $f(w,D|GF,W)$ and $i(w,D|GP,w^*)$ and without knowledge of the rate at which weaned calf prices vary with grazing costs.

For example, the first term in expression (i), reflecting the average quantity of feed required per pound gain (weighted by W/w^2), is positive whereas the second term, reflecting the rate at which average feed quantity per pound gain rises with feeder purchase weight (weighted by $[W/w]-1$), is negative. Hence, rising feed prices increase the algebraic value of the buyer's price-weight slope; that is, they decrease the buyer's willingness to offer premiums on lightweight over heavyweight feeders only if the first term is greater in absolute value than the second. To interpret expression (ii) in table 1, let $D = 0$ when describing the more feed-efficient of two classes of feeder cattle, and $D = 1$ when describing the less feed-efficient. For the likely case in which less feed-efficient cattle also lose efficiency more rapidly under weight gain, the first term in expression (ii) is positive and the second negative. This would, in the absence of specific coefficient

However, these functional dependencies are taken into account in the model evaluations in the following section.

An Approach to the Analysis of Feeder Cattle Price Differentials

Steven T. Buccola

One of the difficulties faced by agricultural economic price analysts is the great variety of subclasses identifiable within commodity categories. Beef cattle price analysts face a particularly difficult problem in this regard. In addition to spatial, temporal, grade, and variety distinctions inherent in most agricultural commodities, cattle markets often discriminate sharply on the basis of weight, age, and sex. Most feeder cattle demand, supply, or price studies focus on a representative steer or heifer defined by an explicit set of characteristics that remains invariant across the data set (Maki). Readers are left to draw inferences for other sets of characteristics. Considerable attention has been devoted to identifying the causes of price differentials observed among lots of feeder cattle sold in a given trading period. But in these studies, readers are left to draw inferences as to how the differentials would change under alternative supply and demand conditions (James and Farris). The intention of the present paper is to provide a general model of break-even feeder cattle prices faced by feeder buyers and sellers, and to utilize the model to investigate the influence of important supply and demand factors on feeder cattle price differentials. Emphasis is placed on price differences by weight and sex category.

Conceptual Basis of Price Differentials

In the United States, prices paid for feeder cattle are established by competitive buyer bidding on successive lots of animals. If prospective buyers view profits as their success indicator, none will pay more for an animal, in the long run, than the difference between its expected sale value and its expected handling and feeding costs. Similarly, although sellers are passive agents in the auction process, few would accept less for an animal, in the long run, than its estimated total cost of production. Thus, break-even prices of buyer and seller define the long-run limits of price bidding. In turn, break-even prices differ according to animal characteristics; that is, according to weight, breed, grade, age, sex, frame size, or other description, because both expected slaughter cattle revenues and animal production costs vary according to these characteristics. Because expected slaughter cattle prices and feed and nonfeed resource prices affect expected feedlot or farm revenues and costs, they also may affect differences in prices realized for different lots of feeder cattle.

To allow more detailed development of this concept, consider a feedlot operator who buys a feeder animal and expects to feed it to slaughter weight and grade. Where W, w are weights of slaughter and marketed feeder animal, respectively, in hundredweight (cwt); r is the price of a prepared feed ration, in dollars per megacalorie ($/Mcal) of metabolizable energy (ME); GF is average daily gain under feed, in hundredweight per day; D is a discrete breed, grade, age, sex, and frame description; $f(w,D|GF,W)$ is average feed efficiency, in Mcal per hundredweight of gain; $g(w,D|W)$ is average daily-basis nonfeed cost of animal maintenance in feedlot, in dollars per day; $h(D)$ is per head cost of animal marketing, in dollars; $P(W,D)$ is slaughter cattle price, in dollars per hundredweight; and p is feeder cattle price, in dollars per hundredweight, expected per head profits (π_b) faced by the feeder cattle buyer are

$$(1) \quad \pi_b = P(W,D)W - r(W-w)f(w,D|GF,W) - (W-w)g(w,D|W)/GF - h(D) - pw.$$

Where appropriate, variables contained in parentheses for this and subsequent equations are assumed to be as function arguments. For example, slaughter cattle price P is a function of slaughter weight W and a set of discrete animal descriptions D. Feed efficiency function $f(w,D|GF,W)$ represents the average feed/gain ratio achieved when a feeder animal of description D is placed on feed at weight w, achieves average daily gain GF, and is sold at preassigned slaughter weight W and slaughter grade. A similar interpretation applies to daily-basis nonfeed cost function $g(w,D|W)$.[1] The right-

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[1] If all cattle represented in functions f and g achieve an identical slaughter grade, slaughter weight W must vary according to characteristic set D. Furthermore, feasible average daily gains on feed (GF) often also vary by characteristic. I here avoid the notational complication of expressing W and GF as functions of D.

has quadratic terms for all variables. This creates a large matrix, for which eigenvalues are needed—perhaps difficult in itself. Further, the approximation ends up with an LP larger in dimension than the Kuhn-Tucker system of the original problem. Thus, if suitable software is available, direct solution by quadratic programming may be better.[2]

Third, eigenvalue-vector programs are available on virtually any computer system that will do the calculations and identify problems in existence (Bellman). Partial diagonalization may be done over small parts of quadratic matrix when the eigenvalues do not exist or when only part of the variables exhibit off-diagonal terms.

Fourth, in the separable programming formulation, grid endpoints for the separable program can be set by approximating all variables with numerical endpoints ranging between plus and minus the square root of a maximum for the quadratic term divided by the eigenvalue. Trial solutions also may be used. The number of grid points depends upon available computer capacity and the magnitude of the eigenvalues.[3] Fifteen points seemed to be reasonable for the various experiments done by the authors. (Error was generally less than 3% in variables, shadow prices, slacks, and objective function prediction.)

Finally, the approximation is numerically sensitive and it appears desirable to use at least six significant digits for the eigenvectors. A slight allowance for error may also be desirable in the equation $\mathbf{X} - \mathbf{QZ} = 0$, when many variables are present (as in Tice, where $-10^{-5} \leq \mathbf{X} - \mathbf{QZ} \leq 10^{-5}$).

Concluding Comments

An exact transformation based upon eigenvalues is discussed above that provides a mechanism for transforming well-formed quadratic programs into separable programs which may then be approximated. The separable programs will have a concave objective in most practical problems and therefore may be solved by linear programming. Using these techniques, the authors have solved a number of problems and contend that the approximation works well, particularly for problems with a low proportion of quadratic variables.

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[2] Further, in the case of E-V problems (where the authors feel that this case would arise most often), the Hazell approximation could be used.

[3] The larger (in absolute value) the eigenvalues, the more points needed for a good approximation.

References

Anderson, J., J. Dillon, and B. Hardaker. *Agricultural Decision Analysis*. Ames: Iowa State University Press, 1977.

Bellman, R. *Introduction to Matrix Analysis*, 2nd ed. New York: McGraw-Hill Book Co., 1970.

Chen, J., and C. Baker. "Marginal Risk Constraint Linear Program for Activity Analysis." *Amer. J. Agr. Econ.* 56(1974):622–27.

Cocks, K. D. "Discrete Stochastic Programming." *Manage. Sci.* 15(1968):72–79.

Duloy, J., and R. Norton. "CHAC: A Programming Model of Mexican Agriculture." *Multilevel Planning: Case Studies in Mexico*, ed. L. Goreaux and A. Manne, pp. 291–337. Amsterdam: North-Holland Publishing Co., 1973.

———. "Prices and Incomes in Linear Programming Models." *Amer. J. Agr. Econ.* 57(1975):591–600.

Freund, R. J. "The Introduction of Risk into a Programming Model." *Econometrica* 24(1956):253–63.

Hadley, G. *Nonlinear and Dynamic Programming*, chap. 4. Reading, Mass.: Addison-Wesley Publishing Co., 1964.

Hazell, P. "A Linear Alternative to Quadratic and Semivariance Programming for Farm Planning under Uncertainty." *Amer. J. Agr. Econ.* 53(1971):53–62.

Lemke, C. E. "Bimatrix Equilibrium Points and Mathematical Programming." *Manage. Sci.* 11(1965):681–89.

McCarl, B., and T. Spreen. "Price Endogenous Mathematical Programming As a Tool for Sector Analysis." *Amer. J. Agr. Econ.* 62(1980):87–102.

Miller, C. "The Simplex Method for Local Separable Programming." *Recent Advances in Mathematical Programming*, ed. R. Graves and P. Wolf. New York: McGraw-Hill Book Co., 1963.

Newman, P. "Some Notes on Stability Conditions." *Rev. Econ. Stud.* 27(1959):1–9.

Plessner, Y., and E. O. Heady. "Competitive Equilibrium Solutions with Quadratic Programming." *Metroeconometrica* 17(1965):117–30.

Polito, J., B. McCarl, and T. Morin. "Solution of Spatial Equilibrium Problems with Benders Decomposition." *Manage. Sci.*, forthcoming.

Rae, A. N. "Stochastic Programming, Utility, and Sequential Decision Problems in Farm Management." *Amer. J. Agr. Econ.* 53(1971):448–60.

Thomas, W., L. Blakeslee, L. Rogers, and N. Whittlesey. "Separable Programming for Considering Risk in Farm Planning." *Amer. J. Agr. Econ.* 54(1972):260–66.

Takayama, T., and G. Judge. *Spatial and Temporal Price and Allocation Models*. Amsterdam: North-Holland Publishing Co., 1971.

Tice, T. "An Investigation of Nitrogen Application under Uncertainty." Ph.D. thesis, Purdue University, 1979.

Wolfe, Philip. "The Simplex Method for Quadratic Programming." *Econometrica* 27(1959):382–98.

$$(6)\qquad Q = \begin{pmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ \frac{1}{\sqrt{2}} & \frac{-1}{\sqrt{2}} \end{pmatrix}.$$

Then the problem becomes

$$\max\ (100\ 90)\begin{pmatrix} X_1 \\ X_2 \end{pmatrix} + (Z_1 Z_2)\begin{pmatrix} -.25 & 0 \\ 0 & -1.75 \end{pmatrix}\begin{pmatrix} Z_1 \\ Z_2 \end{pmatrix}$$

$$(7)\qquad X_1 + X_2 \le 100$$

$$X_1 - \frac{1}{\sqrt{2}} Z_1 - \frac{1}{\sqrt{2}} Z_2 = 0$$

$$X_2 - \frac{1}{\sqrt{2}} Z_1 + \frac{1}{\sqrt{2}} Z_2 = 0$$

$$X_1 \ge 0,\ X_2 \ge 0.$$

A grid of points may then be chosen for Z_1 and Z_2 via separable programming and the problem solved as a linear program.

Comparison with Alternative Approximations

The fundamental question regarding the above approximation is: So what—why should I use it? The approximation needs to be placed in context. Namely, its adequacy must be assessed versus other approximations. A complete comparison of possible approximations is beyond the scope of this paper. Rather, the only approximations addressed will be those developed in Thomas et al., and in Duloy and Norton (1975) and Hazell.

Thomas et al. presented an approximation procedure for the E-V problem, that could easily be applied to the general quadratic program above, which is an application of the separable transformation given in Hadley (p. 119). The approximation adds two new variables which then are separable and two constraints for each cross-product term. The Thomas et al. case clearly deals with the above QP problem in its full generality. General separable programming rather than linear programming is required because the cross-product terms can be either positive or negative.

Duloy and Norton (1975) also provide an approximation procedure that uses separable programming to approximate a quadratic problem. This procedure is most suitable for a diagonal quadratic matrix, although Duloy and Norton discuss how to handle substitution. The procedure, however, does not easily handle the general problem outlined above. Hazell provided the MOTAD approximation for the E-V problem. MOTAD uses the data directly, from which the variance-covariance matrix would normally be formed. MOTAD, in using this data, solves a problem related to, but different from, the E-V problem.

Fundamentally, the eigenvalue transformation is not an approximation; rather, it is an exact transformation. However, when the terms $Z'\Omega Z$ are computed via separable programming, then this scheme becomes an approximation. Implicit, therefore, in the above approximation descriptions are some of the answers to the question on why use this approximation. Specifically:

(*a*) The eigenvalue-based approximation is good for quadratic matrices which are not diagonal (or for nondiagonal parts of quadratic matrices). Diagonal parts can be handled more directly via separable programming (Miller) as in Duloy and Norton (1975).

(*b*) The eigenvalue-based approximation uses linear programming and adds one separable variable (which is approximated via a grid) and one constraint for each variable in the quadratic matrix. If there are many interactions, this would be a smaller problem than the Thomas et al. problem.

(*c*) The eigenvalue approximation solves the quadratic program directly and not a different problem, as in Hazell. This may be desirable if one wishes to maintain correspondence with a theoretical utility function as in Freund.

Further Comments

Relative to the approximation, let us make several further comments. First, a feature of quadratic programming is that when a variable with a quadratic objective term enters what ordinarily would be a linear program, then the whole problem has to be dealt with as a quadratic program. Normally, if one is not using decomposition, as in Polito, McCarl, and Morin, then one would apply a quadratic programming algorithm that would work on the Kuhn-Tucker conditions of the problem (as in Wolfe or Lemke). This leads to a larger system of equations and also requires the complementary conditions to be dealt with. Efficient software for large problems of this sort is not widely available. The approximation above then may be desirable for large problems that are to a great extent linear with a few quadratic variables. Such formulations occur repeatedly in the literature (see, for example, [*a*] spatial equilibrium problems in Takayama and Judge, Duloy and Norton (1975), and Plessner and Heady; and [*b*] the theoretically derived E-V problems in Cocks, Rae, and Tice). The approximation would work well in these cases as long as the quadratic matrix is symmetric and not diagonal. This, in fact, is the problem for which the approximation was developed (Tice) and where it would appear to be most desirable.

Second, as is implicit in the paragraph above, the approximation is not at its best for a problem which

Linearizing Quadratic Programs through Matrix Diagonalization

Bruce A. McCarl and Thomas F. Tice

Quadratic programming formulations are common in applied agricultural economics research. Important problems portraying behavior in the face of risk (e.g., E-V analysis as discussed in Anderson, Dillon, Hardaker) and market equilibrium (Takayama and Judge) have been formulated as quadratic programs. However, quadratic programming problems are more difficult to solve than linear programs and software is not generally available for large quadratic programs. Consequently, many approximations have been proposed (and in many practical applications have been substituted) for quadratic formulations (e.g., Duloy and Norton 1975; Hazell; Chen and Baker; Thomas, Blakeslee, Rogers, Whittlesey). The purpose of this paper is to introduce yet another approximation procedure for quadratic programs, briefly contrast this scheme with other common approximations, discuss its properties, and discuss the cases under which use of this approximation appears desirable. The approximation (developed and applied in Tice) is based upon matrix diagonalization.

Background and Approximation Development

For a symmetric matrix (**A**), where the eigenvalues and vectors exist, then pre- and post-multiplication of the original matrix (**A**) by matrices found from the matrix (**Q**) composed of the eigenvectors (as columns) results in a diagonal matrix with the eigenvalues on the diagonal, i.e.,

$$\mathbf{Q}'\mathbf{A}\mathbf{Q} = \Omega, \tag{1}$$

where **Q** is the matrix of the eigenvectors; **Q**′ is its transpose and Ω is a matrix with elements equal to the eigenvalues on the diagonal, zero elsewhere:

$$(\Omega)_{ii} = \lambda_i;\ \mathbf{Q}(\Omega)_{ij} = 0_{i \neq j}.$$

Using these results an approximation may be formulated. Given a quadratic program with linear (**Y**) and quadratic (**X**) components,

$$\begin{array}{lll} \text{maximize } \mathbf{CX} + \mathbf{X}'\mathbf{AX} + \mathbf{dY} & & \\ \mathbf{FX} & + \mathbf{GY} \leq \mathbf{b} & \\ \mathbf{X}, \mathbf{Y} & \geq \mathbf{0}, & \end{array} \tag{2}$$

where **A** is symmetric[1] and negative definite, introduce new variables so that

$$\mathbf{X} = \mathbf{QZ}, \tag{3}$$

where **Q** is the matrix of eigenvectors of **A**. Substituting for **X**, the quadratic term above becomes $\mathbf{Z}'\mathbf{Q}'\mathbf{AQZ}$ which is diagonal and equals **Z**. The quadratic program then becomes

$$\begin{array}{ll} \max & \mathbf{CX} + \mathbf{Z}'\,\Omega\,\mathbf{Z} + \mathbf{dY} \\ & \mathbf{FX} \qquad\qquad + \mathbf{GY} \leq \mathbf{b} \\ & \mathbf{X} - \mathbf{QZ} = 0 \\ & \mathbf{X}, \mathbf{Y} \geq \qquad \mathbf{Z} \gtrless \mathbf{0}, \end{array} \tag{4}$$

The term $\mathbf{Z}'\,\Omega\mathbf{Z}$, however, can be written as $\sum_{i=1}^{n} \mathbf{Z}_i^2\lambda_i$, which is separable and allows approximation via separable programming—grid linearization (Miller or as in Duloy and Norton). Further, the eigenvalues of a negative definite matrix are all negative; thus, if the original problem is well-formed, the term $\mathbf{Z}\,\Omega\,\mathbf{Z}$ is concave and, following Hadley, the separable problem may then be solved as a linear program (p. 124).

Example

Given the problem

$$\max\ (100\ 90)\begin{pmatrix} \mathbf{X}_1 \\ \mathbf{X}_2 \end{pmatrix} + (\mathbf{X}_1\mathbf{X}_2)\begin{pmatrix} -1 + & .75 \\ .75 & -1 \end{pmatrix}\begin{pmatrix} \mathbf{X}_1 \\ \mathbf{X}_2 \end{pmatrix}$$

$$\begin{array}{l} \mathbf{X}_1 + \mathbf{X}_2 \leq 100 \\ \mathbf{X}_1 \geq \mathbf{0};\ \mathbf{X}_2 \geq 0. \end{array} \tag{5}$$

The eigenvalues are $(-.25\ -\ 1.75)$ and the associated matrix of eigenvectors is

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[1] **A** will ordinarily be symmetric in most applications as (*a*) **A** is symmetric for variance matrices in E-V formulations, or (*b*) **A** can be made symmetric simply by averaging the cross products. In supply-demand type problems, asymmetric matrices must be handled carefully as the discussion in McCarl and Spreen points out.

tween the two models. The chi-square statistics testing this hypothesis for both pairs of equations are given in table 3. These statistics are significant, indicating that in both models distinctly different forces affect the amount of the loan granted by lenders in the liberal group versus those in the conservative grouping.

Summary

The results of this experiment indicate that the surveyed lenders (as a group) were responsive, in terms of the amount of the loan approved, to the borrower's financial position (table 2). Further, these results suggested that the amount of land owned, even though that land was appreciating in value, was not necessarily a good indicator of nonreal estate credit capacity.

The loan responses were more intensively analyzed using an estimation technique which incorporates the doubly truncated nature of the dependent variable, the amount of loan received. The dependent variable has two points of truncation in that negative loans are not possible and the maximum amount of loan requested was $60,000. Preliminary analysis of these data suggested that the lenders tended to respond as two separate groups. A secondary purpose of the research then became to test if these two groupings of lenders responded differently to changes in the firm's financial structure.

Analysis of lender responses indicated that both lender groupings considered the borrower's net worth and income-generating potential as major determinants of credit-generating capacity. The two groups of lenders differed in their view as to the importance of short-term equity and the value of the farmer's leverage ratio. Lenders in the conservative grouping were very responsive to changes in short-term equity, whereas lenders in the liberal grouping were not responsive to changes in this variable. Lenders in both groupings responded to changes in the leverage ratio, but a given increase in that ratio would reduce credit availability by a much greater amount for conservative lenders than it would for lenders in the liberal grouping. These differential responses between the two lender groupings were found to be significant using a chi-square test.

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References

Baker, C. B. "Credit in the Production Organization of the Firm." *Amer. J. Agr. Econ.* 50(1968):507–20.

Barry, P. J., and C. B. Baker. "Reservation Prices on Credit Use: A Measure of Response to Uncertainty." *Amer. J. Agr. Econ.* 53(1971):222–27.

Barry, P. J., and D. R. Willmann. "A Risk-Programming Analysis of Forward Contracting with Credit Constraints." *Amer. J. Agr. Econ.* 58(1976):62–70.

Brake, J. R., and E. Melichar. "Agricultural Finance and the Capital Markets." *A Survey of Agricultural Economics Literature*, vol. 1, ed. Lee R. Martin, pp. 416–94. Minneapolis: University of Minnesota Press, 1977.

Hopkin, J. A., P. J. Barry, and C. B. Baker. *Financial Management in Agriculture.* Danville, Ill.: Interstate Publishers, 1973.

Irwin, G. D., and C. B. Baker. *Effects of Lender Decisions on Farm Financial Planning.* University of Illinois Agr. Exp. Sta. Bull. 688, 1962.

Kadlec, J. E., and B. F. Jones. "Outlook and Management Considerations for Corn Belt Grain Farming 1977–1982." *J. Amer. Soc. Farm Managers and Rural Appraisers* 42(1978):19–26.

Melichar, E. "Some Current Aspects of Agricultural Finance and Banking in the United States." *Amer. J. Agr. Econ.* 59(1977):967–72.

Nelson, F. D. "On a General Computer Algorithm for the Analysis of Models with Limited Dependent Variables." *Ann. Econ. and Social Measure.* 5(1976):493–509.

Plaxico, J. S., and D. D. Kletke. "The Value of Unrealized Farm Land Capital Gains." *Amer. J. Agr. Econ.* 61(1979):327–30.

Rosett, R. N., and F. D. Nelson. "Estimation of the Two-Limit Probit Regression Model." *Econometrica* 43(1975):141–46.

Scott, J. T., Jr. "Costs of Corn and Soybean Production with and without Land." *Effects of High Land Prices*, pp. 84–96. Dep. Agr. Econ. AE-4461, University of Illinois, 1978.

Smith, A. G., and C. B. Baker. "The Effect of Real Estate Debt Commitments on Non-Real Estate Credit and Liquidity of the Farm." *Illinois Agr. Econ.* 9(1969):1–6.

Tobin, J. "Estimation of Relationships for Limited Dependent Variables." *Econometrica* 26(1958):24–36.

TROLL. "Qualitative and Limited Dependent Variable Models." IPA Publications Office D0070, Massachusetts Institute of Technology, 1976.

U.S. Department of Agriculture. *Balance Sheet of the Farming Sector.* Washington, D.C.: AIB No. 411, 1977.

Table 3. Model Estimates for Selected Credit-Related Variables

Equation	Variables				
	STE	*INC*	*NW*	*BUSS*	*EXP*
*C*1	1.81	2.73	.652	−11.9	−.023
	(1.68)	(1.36)	(2.96)	(−1.33)	(−.080)
*L*1	−.184	3.59	.649	−.509	.378
	(−.155)	(1.70)	(3.18)	(−.050)	(1.52)
	$\chi^2_7 = 100$				
	LEV	*NW*	*BUSS*	*EXP*	
*C*2	−13.1	.808	−11.9	−.026	
	(−2.90)	(4.45)	(−1.33)	(−.091)	
*L*2	−6.55	.690	−.358	.378	
	(−1.44)	(4.04)	(−.035)	(1.51)	
	$\chi^2_8 = 99.0$				

where:

STE is current assets less current liabilities (in thousands of dollars); LEV, debt/net worth; INC, income for past year (in thousands of dollars); EXP, experience of lender, in years; BUSS, percentage of institution's loans which are agricultural; and NW, net worth (in thousands of dollars).

Note: Numbers in parentheses are the ratio of the estimate to its standard error. The chi-square statistics test the hypothesis that the respective slope coefficients, intercepts, and standard errors are different for the paired relationships. Hence, the degrees of freedom in each test are the number of slope coefficients estimated plus two.

variations in financial structure. Therefore, a large-sample likelihood ratio statistic was used to test if all of the parameters in each pair of equations are identical. Because the impact of the independent variables on expected loan and probability of a loan is nonlinear, the intercept term and the variance of the disturbance term also are included under the null hypothesis of parameter equality be-

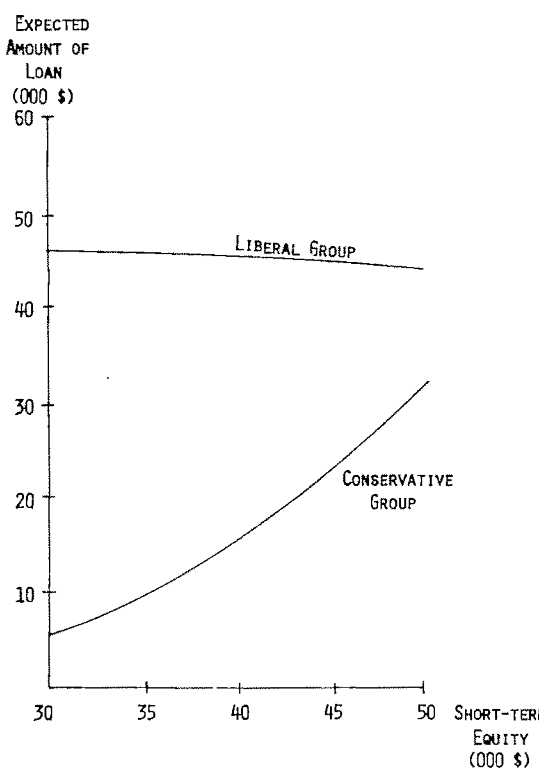

Figure 1. Effect of amount of short-term equity on expected amount of loan

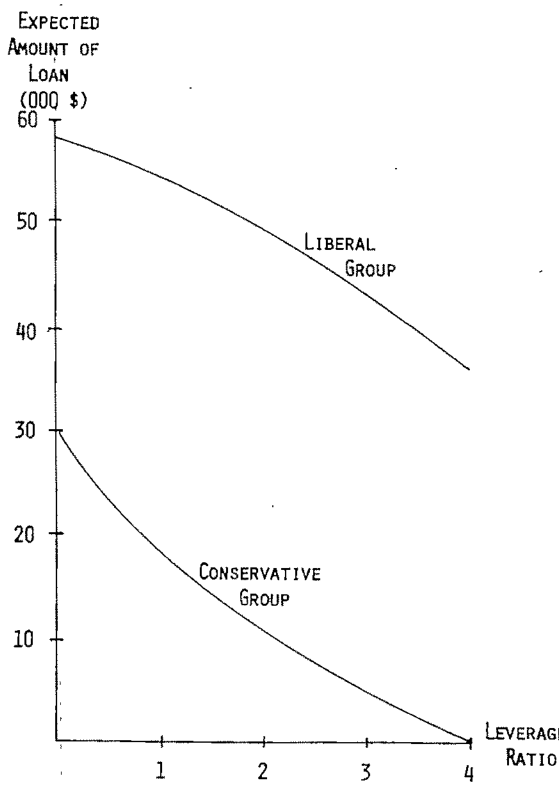

Figure 2. Effect of leverage ratio on expected amount of loan

Factors Affecting Credit Responses of Lenders

Agricultural finance texts suggest that three factors are important in credit analysis: repayment potential, expected returns, and risk-bearing ability (Hopkin, Barry, and Baker). Therefore, specific models were formulated to determine if these factors also are regarded as significant by the lenders involved in this experiment.

To test the importance of the above factors in credit analysis, two regression models are estimated by the ML procedure described, with amount of borrowed funds obtained as the observed dependent variable (W_t). In each model selected variables representing the credit factors previously specified are included in the regression equation. The first model focused on the role of the income-generating capacity of the firm. The second utilized the leverage variable to represent risk-bearing capability. Both models include net worth to indicate the repayment capacity of the borrowing firm. In addition to the variables just discussed, other farm financial and institutional variables were considered in each regression equation, and those that exhibited substantial explanatory power were included.

During preliminary model construction and data analysis, it became apparent that there was considerable variation in individual lender response. For example, two lenders may have responded in a similar fashion to variations in the financial position of the applicant, but one lender consistently would loan a greater quantity of funds than the second for each of the five experimental situations. This variation between lenders did not prove to be strongly related to relevant lender or lending institution characteristics.

To provide a better basis for evaluating this variation, the average loan amount granted over the five loan situations was computed for each of the thirty-three institutions. Examination of these average loan amounts indicated that the lenders' responses tended to fall into two groups with respect to the absolute size of loan granted. One of these groups, which we call the liberal group, was composed of twenty lenders whose average loan response was in excess of $30,000. The remaining thirteen lenders, whose average loan response was less than $30,000, are called the conservative group. To reduce this variability associated with the lender groupings, separate regression equations—one for the liberal and one for the conservative group—are estimated for both of the models discussed previously.[3] A secondary purpose of the analysis then became to assess the extent to which the lenders in each of these groups differed in the manner they responded to the firm's financial structure.

Estimation results of the four regression equations (two for each model) are presented in table 3.[4] Equation (C1) relates to the conservative grouping of lenders and (L1) refers to those in the liberal group. These results indicate that lenders in both groupings regard both the income-generating potential and the net worth of the prospective borrower as important factors in determining the amount of loan to approve. For both lender groupings a $1,000 increase in net worth of the prospective borrower would generate approximately $400 in additional credit capacity (all other variables at sample mean levels). Those in the liberal grouping, however, tended to be more influenced by the income-generating potential of the firm than were those in the conservative group. A $1,000 increase in income potential expanded the potential loan by about $2,200 and $1,800, respectively.

A major difference between the lenders in the two groupings is reflected in their response to the level of short-term equity the borrower possesses. This relationship is illustrated graphically in figure 1. Those lenders in the conservative groupings were willing to increase loan amounts by about $1,400 for each $1,000 increase in short-term equity. In contrast, liberal lenders regarded short-term equity as an unimportant factor (as long as other financial variables remained constant).

Equations (C2) and (L2) relate to the conservative and liberal groupings, respectively. Again the two groupings concur in the crucial role of net worth as a measure of the applicant's collateral position. Both groupings also regard the risk-bearing capacity of the firm, as measured by its leverage ratio, as a significant variable. However, the rate at which the loan amount decreases as the leverage ratio increases is sharply different between the two groupings. This differential, and the disparity in the absolute amount of the loan, is shown in figure 2. Whereas an increase of 0.5 in the leverage ratio reduces the loan received by about $2,700 for the liberal grouping (in the range of ratios from 0.5 to 3.0), this same increase would reduce the loan amount by $3,900 for lenders in the conservative grouping.

As noted previously, dividing the lenders into two groupings precipitated the question of whether the lenders in each group respond differently to

[3] An alternative to estimating two separate equations would have been to use dummy variables to allow intercept and slope coefficients to vary according to whether a lender was classified as liberal or conservative. However, that specification would make σ constant for both groups. Specification of separate equations for the two lender categories was felt to be more appropriate. In both models the estimated standard deviations (σ) were different at about an 88% level of significance.

[4] The observations in each estimated regression clearly are not independent because five observations are drawn from each lender and all five observations for a given lender are included in the same equation. However, to get a comparable sample size from separate lenders, it would have been necessary to contact 165 lenders, an option beyond the limitations of the study. The implied loss of independence is ameliorated by the inclusion in each model of two variables (*BUSS* and *EXP*) characterizing the lending institutions. Thus each variable has identical values for all five observations. These variables purge u_t of variation unique to a given institution relating to *BUSS* and *EXP*.

age ratios of Situations 4 and 5 relative to Situations 2 and 3, respectively. The loan responses of these lenders are consistent with those found by Smith and Baker indicating that debt commitments associated with the purchase of land can reduce the availability of non-real estate credit. They also underscore the need for evaluating the conditions under which increases in net worth resulting from appreciation in land values provide additional capacity to generate debt-financed expansion of the farm firm (Plaxico and Kletke).

Estimation of a Model Explaining Lender Responses

The responses of table 2 provide insights as to the effect of debt structure on credit reserve but do not give estimates of quantitative relationships between financial variables and lender responses. Therefore, a second phase of this analysis was to estimate these relationships utilizing an estimation procedure appropriate for the particular situation under analysis.

Because the hypothetical borrower could not receive more than the amount requested and negative loans are disallowed, the dependent variable in this analysis, the amount of the loan received, is truncated at both tails of its distribution. Such a model is simply a more general model of the one discussed by Tobin, where the dependent variable is truncated only at the lower end of its distribution. As discussed in Tobin, multiple regression is not appropriate when there is a concentration of observations at a limit for the dependent variable. If our concern were only with whether a loan of some amount would be granted, probit or logit analysis would be appropriate. However, these latter approaches deprive the economic analysis of an estimate of the size of expected loan given a specific set of values for the independent variables. Therefore, an estimation approach which incorporates the doubly truncated nature of the dependent variable is utilized. This approach is a special case of a general model with numerous discontinuities in the observed dependent variable (Nelson).

The proposed model may be written as

$$
(1)\quad \begin{aligned} W_i &= 0 \text{ when } Y_i \leq 0 \\ W_i &= 60, \text{ when } Y_i \geq 60 \\ W_i &= Y_i, \text{ when } 0 \leq Y_i \leq 60, \end{aligned}
$$

where Y_i is a linear combination of the independent variables, X_i, plus an error term and is defined as:

$$
(2)\qquad Y_i = \beta' X_i + u_i,
$$

where β is an unknown coefficient vector to be estimated. The u_i are normally and independently distributed error terms with mean zero and variance σ^2. The variable W_i is the observed amount that would be loaned in thousands of dollars. (The constraint value, 60, correlates to the maximum loan amount requested, \$60,000.) The independent variables, X_i, indicate characteristics of the given loan application as well as attributes of the individual lender and lending institution considering the loan. Thus, the Y_i can be interpreted as latent indicators of how much should be loaned given the specific application and lender. The actual amount loaned, W_i, is determined according to how Y_i is classified in (1).

In their seminal article on models with doubly truncated limited dependent variables Rosett and Nelson recommend estimation of β and σ by maximum likelihood (ML) methods.[2] The system of equations which results with the maximum likelihood method is nonlinear and must be solved by iterative methods. Thus initial values for the parameter estimates are required. Rosett and Nelson propose using OLS estimates of those observations where $W_i = Y_i$. Monte Carlo results presented in their article suggest that such an approach likely will yield reliable final estimates. Hence, that method was employed in this analysis. Statistical inference in this study is performed on the estimated parameters by the use of likelihood ratio statistics and the assumption that the estimates are asymptotically normally distributed.

Given the estimated parameters, $\hat{\beta}$ and $\hat{\sigma}^2$, the model in (1) and (2) can be used to predict the probability of a loan being extended and the expected value of loans for given levels of the independent variables. Letting $\hat{Y}_i$ be the predicted value of Y_i given X_i and $\hat{\beta}$, the probability of a loan being extended is simply the probability that $\hat{Y}_i$ is greater than zero where $\hat{Y}_i$ is normally distributed with mean $\hat{Y}_i$ and variance $\hat{\sigma}^2$. The expected value of W_i given X_i is computed as

$$
(3)\qquad E(W_i|X_i) = \int_{-\infty}^{\infty} \frac{1}{\sigma} Z\left(\frac{y - \hat{\beta}' X_i}{\sigma}\right) g(y)\,dy,
$$

where $g(y) = 0$ for $y \leq 0$, $g(y) = y$ for $0 < y < 60$, and $g(y) = 60$ for $y \geq 60$. ($Z[\cdot]$ is the standard normal density function.)

An important implication of (3) is that in general a unit increase in an independent variable does not result in an increase in expected value equal to that variable's slope coefficient. Instead, the impact of a unit increase in an independent variable on expected loan is a function of the level of that variable and the other independent variables in the model. The closer the expected loan is to either the upper or lower limits, the less the impact of a unit change in an independent variable.

---

[2] The likelihood function, L, is defined as

$$
L = \prod_{s_1} P\left(\frac{-\beta' X_i}{\sigma}\right) \prod_{s_2} \frac{1}{\sigma} Z\left(\frac{W_i - \beta' X_i}{\sigma}\right) \prod_{s_3} \left\{1 - P\left(\frac{60 - \beta' X_i}{\sigma}\right)\right],
$$

where s_1, s_2, and s_3 denote the number of observations where $W_i = 0$, $W_i = y_i$, and $W_i = 60$, respectively, $P(\cdot)$ denotes the standard normal cumulative probability distribution function, and $Z(\cdot)$ is the standard normal density function.

Table 1. Selected Financial Data Presented to Lending Officers

	Situation				
Item	1	2	3	4	5
Projected cash flow residual[a]	9,835	5,110	1,555	6,893	2,315
Net worth	125,840	101,105	78,460	118,375	94,465
Current ratio[b]	3.70	2.58	2.46	2.49	2.28
Leverage ratio[c]	0.657	1.062	1.658	1.862	2.478

[a] Expected cash receipts minus expected cash expenditures in the coming year.
[b] Current assets divided by current liabilities.
[c] Total liabilities divided by net worth.

tionally, considerable production and financial data were available to the lender. However, only those items the lender requested were supplied. Available financial statements included past and projected income, net worth, and cash flow statements.

Many farm operators considering a decision to invest relatively large sums of money in fixed assets are concerned that such a commitment will have an adverse effect on their ability to generate borrowed funds to continue operation of their business. In this study, therefore, five loan situations were devised in which the borrower was said to have recently purchased farmland and now desired intermediate credit. In each of these situations the borrower requested $60,000 to replace a crucial piece of machinery, the combine, and to establish a grain storage and drying facility. If the original loan request was thought to be too high, the lender was requested to make a loan for the maximum amount feasible.

Selected financial data for the five simulated loan situations are given in table 1. In the first three situations the applicant had recently purchased 40 acres and in the last two situations had purchased 80 acres of his 400-acre, predominately cash grain farm. As shown in table 1, these five situations were structured to represent varying degrees of financial stress for the hypothetical farmer borrower.

For each financial situation, the average amount which would have been loaned by the lenders surveyed is presented in table 2. These average responses vary from $20,000 in Situation 3 to over $47,000 in Situation 1. An applicant with the relatively strong financial characteristics described in Situation 1 would have received a loan, but of varying amounts, from all thirty-three lenders. The minimum which would have been provided in this instance was $20,000, sufficient for purchasing a used combine but not for erecting any grain-drying and storage facilities.

For Situations 3 and 5, the comparatively weaker financial position of the borrower resulted in average loans of about $20,000, sharply lower than in the other three circumstances. A considerable number of lenders indicated they would have refused to grant any loan (13 and 15 lenders, respectively). These responses indicate that the concept of credit reserve, i.e., the capacity to borrow, should be of concern to farm operators. Potential borrowers with financial characteristics as depicted in Situations 3 and 5 may have so diminished their credit reserve that their ability to borrow in order to survive adverse occurrences would be jeopardized.

The loan responses of table 2 also indicate that the amount of land owned by the potential borrower, by itself, is not a good indicator of loan response. For example, the loan responses of Situation 2 and Situation 4 are nearly equal, even though the prospective borrower in Situation 4 was described as owning twice as much land as the applicant of Situation 2. (A similar comparison is possible between Situations 3 and 5.)

One positive aspect of the larger land purchase is reflected by the larger net worths of Situations 4 and 5. These expanded net worths are in large part due to inflation in land values subsequent to the land purchase. A negative aspect of the larger land purchase, however, is reflected in the higher lever-

Table 2. Responses of Lenders to Loan Requests

	Situation				
	1	2	3	4	5
Average loan amount received ($)	47,400	35,700	20,000	37,000	24,200
Number of lenders who would have refused to grant any amount of loan	0	4	15	4	11

Impact of Farm Financial Structure on the Credit Reserve of the Farm Business

S. T. Sonka, B. L. Dixon, and B. L. Jones

The concept of credit reserve and its interaction with other firm decisions has become particularly important to the farmer because of two factors recently affecting American agriculture. One of these is the greater price variability associated with many agricultural products. The second is the recent escalation of farm input prices, particularly with respect to major asset items such as farmland (Melichar, Scott). In adjusting to such changing operating conditions, farm operators have substantially increased their use of borrowed funds. Between 1970 and 1977, liabilities of the farming sector increased by over 90% (U.S. Department of Agriculture). Although borrowing has been historically an important source of capital for farmers (Brake and Melichar), this expansion in the use of borrowed funds makes understanding the ramifications of debt use a high priority information need.

The credit reserve concept, i.e., the individual's unused capacity to borrow funds (Baker), is a central feature in the process of understanding the use of debt capital. If an individual farmer chooses to maintain a credit reserve, this decision is not without costs and benefits. The costs of this decision are the foregone expected net benefits of utilizing additional borrowed funds. The intangible benefits associated with a reserve result from maintenance of firm liquidity. Therefore we can think of the decision to maintain a credit reserve as a form of risk-averse behavior in response to uncertainty (Barry and Baker). This response would be expected to become more important as farmers perceive the conditions in which they operate as being increasingly uncertain (Kadlec and Jones).

For a specific farm operator, a quantitative expression for credit reserve can be described as the difference between capital limits imposed by external credit rationing and the amount actually borrowed by that individual (Barry and Baker). Describing credit reserve in this manner specifies the two parties involved in determining the size of the credit reserve. The first party is the farm operator and the second is the lender who decides upon the level of external credit rationing.

Past research has shown that farmer actions, such as the order in which loans for particular items are requested or forward contracting a portion of a crop, can affect the amount of credit available (Irwin and Baker; Barry and Willmann). An additional set of farmer-controlled variables which should have an impact on the level of external credit limits is reflected in the asset structure of the farm business (Hopkin, Barry, Baker). This paper reports on an experiment conducted to estimate quantitatively the relationship between the asset structure of the farm firm and its credit reserve for a specific agricultural situation.

Soliciting Lender Responses to Farm Financial Structure

To assess quantitatively the impact of the firm's financial structure on its external credit limits, information was needed which related lender credit reactions to variations in the components of a farm's financial position. In early 1977, a simulated borrowing experiment was conducted with thirty-three agricultural lenders in east central Illinois.[1] At each of these institutions (thirty commercial banks and three Production Credit Associations), an agricultural credit officer was asked to evaluate loan requests of hypothetical farm operators and to indicate the loan response that such requests would receive.

Several items of information were made available to each loan officer as he requested them. One item was a detailed biography of the borrower. This biography described the borrower as a college graduate in agriculture with four years experience as an independent farmer. The applicant was said to have dealt with that institution for the entire time he had farmed and to have a good credit history. Addi-

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[1] As detailed by Baker, observation of lender responses to the financial condition of prospective borrowers is a subtle problem. Utilization of an attitudinal survey of lenders may result in conditioned responses by lenders rather than responses indicating their actual behavior. Examination of actual loans, on the other hand, will only provide information on loans granted and would exclude conditions where loans are refused. These concerns plus positive experiences with the experimental approach by other researchers (Barry and Willmann, Irwin and Baker, and Smith and Baker) indicated that a simulated experiment would be most appropriate in this instance. In order to assure as realistic an experimental situation as possible, the financial situations specified were pretested with a small number of individuals with lending experience in the geographical area. After adjustment, these individuals indicated that the financial conditions developed for the experiment would be representative of actual farm firms of the type specified.

However, the aggregate response is the net response of many decision makers. It is possible that certain categories of farmers do not respond as hypothesized. This phenomenon could not be captured with aggregate data. Also we have focused more on the direction of the response than the magnitude of the response. Differential magnitudes in response may be associated with various characteristics such as risk aversion (Gabriel), farm size, or farm type. In short, the extent of the response for any given farm could be expected to be greater or less than the one displayed in the aggregate model.

Although the empirical test of the existence of risk balancing as described in this paper is far from conclusive, owing to the obvious problems associated with aggregation and the possibility of autocorrelation, the results are consistent with the hypothesis. Adequate testing of the risk-balancing hypothesis would require detailed observations of how individual decision makers respond to changes in business risk over significant periods of time. This data requirement may be difficult to satisfy.

The finance activity of the farm firm is a critical and pervasive one which should not be ignored in attempts to model the decision-making process at the farm level. It has been shown that the financing decision is an important consideration in determining total risk, whether risk is defined in terms of income variability or as the probability of the occurrence of a dread event such as cash insolvency.

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References

Baker, C. B., and V. K. Bhargava. "Financing Small-Farm Development in India." *Aust. J. Agr. Econ.* 18(1974):101–18.

Baker, C. B., and J. A. Hopkin. "Concepts of Finance Capital for a Capital Using Agriculture." *Amer. J. Agr. Econ.* 51(1969):1055–64.

Barry, P. J., and C. B. Baker. "Reservation Prices on Credit Use: A Measure of Response to Uncertainty." *Amer. J. Agr. Econ.* 53(1971):222–27.

Barges, Alexander. *The Effect of Capital Structure on the Cost of Capital.* Englewood Cliffs, N.J.: Prentice-Hall, 1963.

Dillon, John L. *The Analysis of Response in Crop and Livestock Production.* New York: Pergamon Press, 1977.

Encarnatión, Jose, Jr. "Constraints and the Firm Utility Function." *Rev. Econ. Stud.* 31(1964):113–20.

Gabriel, Stephen C. "Financial Responses to Changes in Business Risk on Central Illinois Cash Grain Farms." Ph.D. thesis, University of Illinois, 1979.

Halter, A. N., and G. W. Dean. *Decisions under Uncertainty.* Cincinnati, Ohio: South-Western Publishing Co., 1971.

Just, Richard E. "Risk Aversion under Profit Maximization." *Amer. J. Agr. Econ.* 57(1975):347–52.

Kennedy, J. O. S., and E. M. Francisco. "On the Formulation of Risk Constraints for Linear Programming." *J. Agr. Econ.* 25(1974):129–45.

Roy, A. D. "Safety First and the Holding of Assets." *Econometrica* 20(1952):431–49.

Van Arsdell, P. M. *Corporation Finance.* New York: Ronald Press Co., 1968.

Van Horne, J. C. *Fundamentals of Financial Management.* Englewood Cliffs, N.J.: Prentice-Hall, 1974.

Wiens, Thomas B. "Peasant Risk Aversion and Allocative Behavior: A Quadratic Programming Experiment." *Amer. J. Agr. Econ.* 58(1976):629–35.

Wolgin, Jerome M. "Resource Allocation and Risk: A Case Study of Smallholder Agriculture in Kenya." *Amer. J. Agr. Econ.* 57(1975):622–30.

The importance of the relationship between business and financial risk lies in the resultant link between investment and financing decisions. Investment and financing decisions must be made simultaneously, maintaining a balance between risk exposure and expected returns. This relationship also is important when estimating the potential effects of policy-induced alterations in business risk with respect to farm finance.

Preliminary Empirical Evidence

In an attempt to verify the risk-balancing activity described above (i.e., the financial adjustment to changes in business risk), linear regression was used to estimate the coefficients of variables explaining changes in the ratio, $I/(\bar{c}x - I)$. This ratio is the component of financial risk in which the balancing response takes place.

The data used in the regression equation were aggregate income, balance sheet, and farmland price data provided by U.S. Department of Agriculture (USDA) publications, *Farm Income Statistics, Balance Sheet of the Farming Sector,* and *Farm Real Estate Market Developments.* While the various definitions which follow are straightforward, some clarifications are in order. Although cash rental obligations increase financial risk, the available figures on rental payments are "contaminated" with share-type rental payments which do not affect financial risk. Consequently, rental obligations were excluded as an element of financial risk. In addition, data on principal payments on debt are not available, so that the net operating income definition of financial risk was employed.

Although the conceptual framework presented in this paper is micro in nature, we have attempted a preliminary test of the risk-balancing hypothesis using aggregate data. The reason for this is that it was felt that it would be difficult to obtain adequate farm-level data (i.e., a long enough time series for enough farms) to facilitate a test of the hypothesis. Thus, the aggregate results would describe the behavior of the "aggregate of decision makers." We believe that, although inconclusive in itself, this approach may provide a point of departure for future research on the topic.

Factors other than business risk are assumed to influence the decision makers' ability and/or willingness to make adjustments in the firms' financial risk. Among those factors are the average cost of debt capital and the profitability of assets. In addition, changes in the price of land are assumed to affect firm liquidity as credit adjusts to new equity values. Recall that firm liquidity was shown to be instrumental in the risk management of the farm.

Using nationally aggregated data for the period 1949–76, the following model was estimated:

$$FR_t = f(CV_{t-1}, (I/D)_{t-1}, (NI/A)_{t-1}, \%CH\ LND_{t-1}),$$

where CV_{t-1} is a five-year moving coefficient of variation of net operating income for the farm sector of the United States; (CV_{t-1} is based on net operating income for years $t-1$, $t-2$, $t-3$, $t-4$, and $t-5$.); $(I/D)_{t-1}$ is the ratio of total interest payments to total debt in year $t-1$; $(NI/A)_{t-1}$, the ratio of net income to total assets in year $t-1$; $\%CH\ LND_{t-1}$, percent change in the land price index from March year $t-1$ to March year t; and FR_t, the ratio $I/\bar{c}x - I$ in year t.

The regression results (see table 1) indicate an inverse relationship between business risk (CV_{t-1}) and $I/(\bar{c}x - I)$. That is, in the aggregate, there appears to be a financial response to changes in business risk which tends to support the risk-balancing hypothesis.

While the other explanatory variables are of secondary interest here, we will look briefly at their role in explaining changes in the dependent variable. The coefficient for $(I/D)_{t-1}$ is positive and significant, which indicates, as one might expect, that high (low) debt capital costs lead to high (low) financial risk, *ceterus paribus.*

The variable $(NI/A)_{t-1}$ displays a coefficient with the expected sign as well as a high level of significance. All things otherwise the same, greater asset profitability should lead to high debt coverage ratios and lower financial risk.

Finally, as stated earlier, land values influence credit availability positively, increasing liquidity and allowing financial risk also to increase. This relationship is supported by the positive and significant coefficient associated with *%CH LND.*

Summary and Conclusion

The results of this empirical analysis have shown that in the aggregate, farmers make financial adjustments leading to decreased (increased) financial risk in response to a rise (fall) in business risk.

Table 1. Regression Results

	Constant	CV_{t-1}	$(I/D)_{t-1}$	$(NI/A)_{t-1}$	$\%CH\ LND_{t-1}$
Coefficients	−.10	−.24	6.28	−1.58	.20
Standard errors	.075	.129	1.10	.441	.109
T-ratios	−1.35	−1.85*[a]	5.71**	−3.59**	1.82*

R^2 = .92 Durbin-Watson Statistic 1.00***

[a] Single asterisk denotes significant at the 5% level; ** is significant at the 1% level; *** denotes the Durbin-Watson test for autocorrelation is indeterminant.

the release of internally rationed debt capital. Once again, the response to the exogenously induced decline in business risk could involve production or investment decisions, financing decisions, or a combination of the three.

Liquidity and Risk Management

The previous discussion ignores the role that liquidity reserves play in risk management. Baker, along with others, has emphasized the importance of liquidity management in the management of risk on the farm (Baker and Bhargava, Baker and Hopkin, and Barry and Baker). In addition to the liquidity embodied in the tangible assets of the farm, one must consider the liquidity characteristics of a somewhat less tangible asset, credit or borrowing capacity.

It is clear that the level of liquidity reserves exerts at most a small explicit effect on the variability of income or cash flows. However, most of its influence is implicit in that it affects the production organization as well as the financial organization of the farm. That is, if the decision maker regards his reserves of liquid assets as a tool in risk management, used to offset cash deficiencies resulting from an adverse outcome in an uncertain market or production process, the size of these reserves will influence his investment and financing decisions. The larger the reserves of liquid assets, the more willing he will be to select riskier investment alternatives and financial plans.

One method of incorporating this liquidity management dimension into an overall risk management framework is to look at risk in a probabilistic sense. Let us redefine total risk as the probability, α, that one will be unable to generate a minimum level of funds needed for home consumption as well as business requirements after having serviced debt. This can be expressed as

$$(8)\qquad P(cx + \mu - I \leq z) = \alpha,$$

or, as an upper bound,

$$(9)\qquad P(cx + \mu - I \leq z) \leq \alpha.$$

Following Roy and Kennedy and Francisco (pp. 133–35), we can state:[3]

$$(10)\qquad P(cx + \mu - I \leq z) \leq \frac{\sigma_s^2}{[(\bar{c}x + \mu - I) - z]^2},$$

where cx is the random variable, net cash flow; $\bar{c}x$ is expected net cash flow; μ is the liquidity reserve; I is the fixed debt-servicing obligations (i.e., interest and principal); z is the lower limit described above; and σ_s^2 is the subjective variance of net cash flow.

Restricting total risk to be no greater than α, where α is the probability that some critical cash demand cannot be met amounts to the restriction,

$$(11)\qquad P(cx + \mu - I \leq z) \leq \frac{\sigma_s^2}{[(\bar{c}x + \mu - I) - z]^2} \leq \alpha.$$

In other words, the condition prescribed by equation (9) will be met if

$$(12)\qquad \sigma_s \leq \sqrt{\alpha}\,[(\bar{c}x + \mu - I) - z], \text{ or,}$$

dividing both sides of (12) by $\bar{c}x$,

$$(13)\qquad \frac{\sigma_s}{\bar{c}x} \leq \sqrt{\alpha} + \frac{\sqrt{\alpha}\mu}{\bar{c}x} - \frac{\sqrt{\alpha}I}{\bar{c}x} - \frac{\sqrt{\alpha}z}{\bar{c}x}.$$

Moving the terms involving μ, I, and z to the left side of (13) and factoring $\sqrt{\alpha}$,

$$(14)\qquad \frac{\sigma_s}{\bar{c}x} + \sqrt{\alpha}\,\left(\frac{I}{\bar{c}x} + \frac{z}{\bar{c}x} - \frac{\mu}{\bar{c}x}\right) \leq \sqrt{\alpha}\,.$$

The implications of this risk constraint are clear: $\sigma_s/(\bar{c}x)$ is equal to the coefficient of variation of net cash flow and is an index of business risk; $I/(\bar{c}x)$ is the ratio of financial risk to total risk under the variability criterion discussed earlier;[4] $z/(\bar{c}x)$ is the ratio of the critical cash requirement to the expected net cash flow and $\mu/(\bar{c}x)$ is the liquidity reserve divided by expected net cash flow. These items can be considered components of total risk in that if total risk, α, were allowed to vary unrestricted it would be positively related to $\sigma_s/(\bar{c}x)$, $I/(\bar{c}x)$, $z/(\bar{c}x)$ and inversely related to $\mu/(\bar{c}x)$.

It is important to note, in equation (14), that each of the components involving I, z, and μ is weighted by $\sqrt{\alpha}$. Because α necessarily must be a number between zero and one, depending on the decision maker's risk preferences, the impact of changes in these components on total risk can be considerably less than that of business risk, $\sigma_s/(\bar{c}x)$. This phenomenon should be expected, however, since business risk is the underlying source of all risk.

The risk constraint shows that the importance of liquidity reserves as a method of managing risk becomes negligible as business and financial risk approach zero. This is clear since liquidity reserves tend to offset the various sources of risk indicated in equation (14). Also, exogenously based changes in the value of equity, through capital appreciation and/or depreciation, affect the farmer's ability to bear risk. This results from the alteration in liquidity reserves, μ (particularly credit), which occurs as capital appreciates or depreciates in value.

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[3] Roy and Kennedy and Francisco have shown, using Tchebycheff's theorem, that

$$P[cx \leq z^*] \leq \sigma_s^2/(\bar{c}x - z^*)^2,$$

where z^* is a disaster outcome, and cx, $\bar{c}x$, and σ_s^2 are defined as in the text above. In this paper we have defined z^* (which is a constant) to equal $z - \mu + I$ (also all constants). Hence we are able to write equation (11).

[4]
$$\frac{\text{Financial risk}}{\text{Total risk}} = \frac{\dfrac{\sigma_1 I}{\bar{c}x(\bar{c}x - I)}}{\dfrac{\sigma_1 \bar{c}x}{\bar{c}x(\bar{c}x - I)}} = \frac{I}{\bar{c}x}.$$

$$(2)\qquad FR = \frac{\sigma_2 - \sigma_1}{\bar{c}x - I} + \frac{\sigma_1}{\bar{c}x}\,\frac{I}{\bar{c}x - I}.$$

Consider the case where leverage does not induce a change in the variability of net cash flows (i.e., where $\sigma_1 = \sigma_2$). When $\sigma_1 = \sigma_2$, the σ_1 first term of the right side of equation (2) becomes zero, leaving equation (3):

$$(3)\qquad FR = \frac{\sigma_1}{\bar{c}x}\,\frac{I}{\bar{c}x - I}.$$

We see that financial risk is determined by the degree of business risk inherent in the firm $\sigma_1/(\bar{c}x)$, and the relation $I/(\bar{c}x - I)$ which is determined by the financing decision.

Equation (2) reveals the effects of leverage-induced changes in the variability of net cash flows. If the variability of net cash flows declines with use of debt financing because, for example, the decision maker alters his marketing strategy, (i.e., $\sigma_2 < \sigma_1$) financial risk will be lower than if no change in variability occurred. The difference would be determined by the value $(\sigma_2 - \sigma_1)/(\bar{c}x - I)$. Conversely, if variability increased ($\sigma_2 > \sigma_1$), financial risk would be greater than would have been the case had no change taken place: by the amount, $(\sigma_2 - \sigma_1)/(\bar{c}x - I)$.

Risk Balancing

If it is assumed that the decision maker has identified both firm survival and profit maximization as goals, where survival is of primary importance, a lexicographic utility function exists and the decision maker will maximize net returns subject to the constraint that total risk does not exceed a specified level (see Encarnatión and Halter and Dean, pp. 54–57). Risk balancing refers to the adjustment in the components of total risk (i.e., business and financial risk) that results from an exogenous shock to the existing balance. This shock is to be represented by a change in business risk and is viewed within the context of a total risk constraint.

Assuming that there are no leverage-induced changes in business risk (i.e., that $\sigma_1 = \sigma_2$) total risk (TR) is defined as

$$(4)\qquad TR = \frac{\sigma_1}{\bar{c}x - I}, \text{ or}$$

$$(5)\qquad TR = \frac{\sigma_1}{\bar{c}x}\,\frac{\bar{c}x}{\bar{c}x - I}.$$

A total risk constraint can be formed if the maximum tolerable total risk (β) can be identified by the decision maker. Hence, the total risk constraint could be written,

$$(6)\qquad \frac{\sigma_1}{\bar{c}x}\,\frac{\bar{c}x}{\bar{c}x - I} \le \beta.$$

Suppose that, due to a change in an exogenous source such as price support policy or foreign trade policy, σ_1 declines, leaving all the other variables unchanged. Total risk will have declined proportionally, leaving slack in the risk constraint specified in (6). Financial risk also will have fallen proportionally. Because financial risk contributes to the total risk of the firm and is a function of the financing decision, internal capital rationing may occur in order to comply with the risk constraint. Therefore, one might expect debt use and, consequently, financial risk, to adjust to changes in the level of business risk.

It is important to observe at this point that the ratio, FR/TR, is invariant to changes in business risk (assuming a change only in σ_1). Financial risk as a percentage of total risk might change, however, as investment and financial responses to this modification in business risk take place.

The response to a decline in business risk may involve an investment decision as well as a financing decision. If the decision maker maximizes profit subject to a risk constraint, he will search for investment opportunities that increase the value of the objective function. Simultaneously, however, he may be expected to consider the effects of financing alternatives on cash flow, profitability, and overall risk. The process is a complex one, entailing the interaction of the components of risk (i.e., the risk which originates in the investment decision and that which originates in the financing decision). A balance must be met between the effect that the investment has on overall business risk as well as its effects on financial risk.

For a more complete understanding of the role of business and financial risk in the determination of total risk, the expression for total risk, defined as total variability, can be shown to consist of the sum of business and financial risk. If $\sigma_1 = \sigma_2$, and some upper limit, β, is placed on total risk we have

$$(7)\qquad \frac{\sigma_1}{\bar{c}x} + \frac{\sigma_1 I}{\bar{c}x(\bar{c}x - I)} \le \beta.$$

Because the expression for financial risk involves that of business risk, its level is dependent upon the degree of business risk. Let there be an exogenously induced rise in σ_1, and thus a rise in business risk. Assuming there is no slack in the risk constraint, financial risk also will rise, forcing a subsequent risk adjustment in order to comply with the constraint. This adjustment may involve a production or an investment decision, a financing decision, or all three. For example, a strictly financial response would be to refinance some existing debt with either a debt with longer maturity (and thus lower periodic debt service requirements) or with equity capital. Alternatively, a reorganization of farm assets and investments could take place, lowering business risk.

Similarly, if σ_1 were to decline due to some exogenous force, such as a change in foreign trade policy, both business and financial risk would decline leaving slack in the risk constraint. This would allow the introduction of more risky, higher return activities into the production process in addition to

Concepts of Business and Financial Risk

Stephen C. Gabriel and C. B. Baker

There is considerable current interest in methods of limiting the business risk to which farmers are exposed. Some approaches to business risk modification involve insurance, government programs, weather modification, and innovations of individual farmers: technological, to limit the probability of disease and insect damage; and market, to limit the probability of adversity through price fluctuations.

It is recognized that the introduction or modification of risk in the production process affects the pattern of resource allocation and in turn the level of production (Dillon, pp. 102–48, Just, Wiens, and Wolgin). We suggest that there is also a financial response to business risk modification. The differentiation is important in that business risk and financial risk may well be trade-offs in the risk behavior of farmers. Thus, a decline in business risk would lead to the acceptance of greater financial risk, reducing the effects of the diminished business risk on total risk.

In this paper we present a conceptual framework for linking production and investment decisions to the financing decision via a risk constraint. While most of the literature on risk and risk response treats only production and price risk (i.e., business risk), we intend to introduce the notion of financial risk explicitly into the decision-making process.

Business Risk

Business risk is defined to be the risk inherent in the firm, independent of the way it is financed (Van Horne, pp. 207–8). Business risk generally is reflected in the variability of net operating income or net cash flows. A high (low) coefficient of variation of net cash flows, for example, would indicate high (low) business risk. Business risk may be evaluated at a point in time based on the probability distribution of net cash flows.

There are two major external sources of business risk in the agricultural firm. One is the market which produces price variability for both outputs and inputs and uncertain availability and quality of the latter. The other source is the biophysical environment which produces yield or production variability. These elements combine to form the bulk of business risk on the farm. The level of business risk also is influenced by internal factors such as investment decisions and management skills.

Financial Risk

Following Barges (p. 16), financial risk is defined to be the added variability of the net cash flows of the owners of equity that results from the fixed financial obligation associated with debt financing and cash leasing.[1] Also, as mentioned by Van Arsdell (p. 304) and Van Horne (p. 252), financial risk encompasses the risk of cash insolvency. However, this notion will be expanded to include the risk of being unable to meet prior claims with the cash generated by the firm, which is determined by the dispersion of net cash flows and the level of fixed obligations, as well as the firm's pool of liquid resources. Focusing initially on the variability aspects, financial risk (FR) can be specified as:

$$FR = \frac{\sigma_2}{\bar{c}x - I} - \frac{\sigma_1}{\bar{c}x}, \tag{1}$$

where σ_1 is the standard deviation of net cash flows without debt financing; σ_2, the standard deviation of net cash flows with debt financing but before the deduction of debt servicing payments; $\bar{c}x$, expected net cash flows without debt financing; and I, fixed debt servicing obligations.[2]

Equation (1) reflects the change in the coefficient of net cash flows which results from debt financing. Standard deviations of net cash flows without financing and with financing (σ_1 and σ_2, respectively) have been specified since it is possible that lenders or indeed the farmer himself may impose marketing and/or production restrictions which may alter the dispersion of net cash flows owing to the use of debt financing. Also, leverage-induced scale effects may influence the variability of net cash flows. Expected net cash flows may be altered because of scale effects. However, for the sake of simplicity we hold it constant in this analysis. Equation (1) may be rewritten, allowing us to divide financial risk into its components:

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[1] For the balance of this study only debt financing will be referred to as a source of financial risk for purposes of simplicity.

[2] Financial risk could be defined in terms of net operating income or net cash flows. The fixed debt-servicing obligations would involve only interest under the former definition and both interest and principal under the latter.

Hadar, J., and W. Russell. "Diversification of Interdependent Prospects." *J. Econ. Theory* 7(1974):231–40.

Heady, E. "Diversification in Resource Allocation and Minimization of Income Variability." *J. Farm Econ.* 34(1952):482–96.

Johnson, S. R. "Reexamination of the Farm Diversification Problem." *J. Farm Econ.* 49(1967):610–21.

Markowitz, H. *Portfolio Selection—Efficient Diversification of Investments*. New York: John Wiley & Sons, 1959.

Raup, P. "Economics and Diseconomies of Large-Scale Agriculture." *Amer. J. Agr. Econ.* 51(1969):1274–82.

Samuelson, P. "A General Proof That Diversification Pays." *J. Financ. Quant. Anal.* 2(1967):1–13.

Scherer, F. M. *Industrial Market Structure and Economic Performance*. Chicago: Rand-McNally & Co., 1971.

Stovall, John G. "Income Variation and Selection of Enterprises." *J. Farm Econ.* 48(1966):1575–79.

Theil, Henri. *Principles of Econometrics*. New York: John Wiley & Sons, 1971.

U.S. Congress, Congressional Budget Office. *Public Policy and the Changing Structure of American Agriculture*. Washington, D.C., Aug. 1978.

U.S. Department of Agriculture. *Farm Income Statistics*. Washington, D.C.: ESCS Statist. Bull. No. 627, 1979.

White, T., and G. Irwin. "Farm Size and Specialization." *Size, Structure and Future of Farms*, eds. G. Ball and E. Heady. Ames: Iowa State University Press, 1972.

Table 2. Regression Results Based on Diversification Measures Defined on Farm Net Revenue

Independent Variable (t-ratios)	Dependent Variable		
	M_1	M_3	M_4
Constant	.77 (21.1)	.70 (16.5)	.478 (6.05)
Z_1 is partnership	−.0046 (−.25)	−.0088 (−.40)	.028 (.70)
Z_2 is family corporation	.026 (.64)	.016 (.33)	−.013 (−.14)
Z_3 is corporation	.01 (.26)	.0081 (.16)	−.033 (−.37)
D_1	.014 (.59)	.012 (.44)	−.042 (−.83)
D_2	.038 (.94)	.047 (.97)	−.124 (−1.39)
D_3	−.072 (−3.13)	−.095 (−3.53)	−.183 (3.67)
D_4	−.011 (−6.40)	−.14 (−6.99)	.291 (7.39)
S is farm size/acres cropped	−.000054 (−7.19)	−.000071 (−7.96)	.00014 (8.95)
W is net worth/acres cropped	.000028 (1.40)	.000042 (1.75)	−.000085 (−1.90)
E is experience	.0017 (4.00)	.0021 (4.18)	−.0034 (−3.69)
R^2	.15	.18	.20

Note: See table 1 for details.

larger farms are more diversified. Wealthier and less experienced farmers are more specialized. Finally, there is also evidence that corporations are more specialized than farms with other organizational forms.

Evidence reported here suggests that diversification and size (or growth) may be positively linked. Hence, there may not be sufficient economies of scale in a particular commodity to warrant specialization. In general, the results here are consistent with risk theories. That is, the firm diversifies to spread risk and wealthier farmers have fewer incentives to spread risk. However, as with all cross-section studies, questionable causation and the myriad of forces at work lead one to be cautious when interpreting results. The essential point is that these results may be cause for reservation for those supporting policies which are tied to diversified farms that are presumed to be relatively small. Raup and others have suggested that larger farms may be in relatively poorer risk posture than smaller farms. However, the results reported here may not support his hypothesis. The conclusions reached in the analysis here must be tempered by the lack of nonfarm income-generating activities and possibly any unique characteristics specific to the geographical setting. These considerations indicate that positive economic analysis of diversification needs further research in order to delineate more fully the economics of activity choice and the ability of farms to self insure through diversification.

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References

Berry, Charles H. "Corporate Growth and Diversification." *J. Law and Econ.* 14(1971):371–83.

Carter, H. O., and G. W. Dean. "Income, Price and Yield Variability for Principal California Crops and Cropping Systems." *Hilgardia* 30(1960):175–218.

Gardner, B. D., and R. D. Pope. "How is Scale and Structure Determined in Agriculture?" *Amer. J. Agr. Econ.* 60(1978):295–302.

Greve, Robert W., James S. Plaxico, and William F. Lagrone. *Production and Income Variability of Alternative Farm Enterprises in Northwest Oklahoma,* Oklahoma State University Agr. Exp. Sta. Bull. B-536, 1960.

Hackbart, Merlin M., and Donald A. Anderson. " 'On Measuring Economic Diversification': Reply." *Land Econ.* 54(1978):111–12.

Table 1. Regression Results on Diversification Measures Defined on Crop Acreages

Independent Variable (t-ratios)	Dependent Variable M_1	M_2	M_3	M_4
Constant	.670	2.09	.4	.61
	(20.21)	(8.26)	(13.1)	(8.4)
Z_1 is partnership	−.027	3.56	−.0061	.082
	(−1.56)	(2.62)	(−.41)	(2.09)
Z_2 is family corporation	−.048	.818	−.043	.166
	(−1.44)	(3.19)	(−1.57)	(2.22)
Z_3 is corporation	.030	−.125	.034	−.046
	(.84)	(−.45)	(1.17)	(−.57)
D_1[a]	.049	−.295	.064	−.096
	(2.17)	(−1.7)	(3.15)	(−1.9)
D_2[b]	.019	.0826	−.01	.0042
	(.50)	(.28)	(−.29)	(.05)
D_3[c]	−.060	.68	−.021	.18
	(−2.78)	(4.10)	(−1.09)	(3.72)
D_4[d]	−.141	1.32	−.018	.362
	(−7.96)	(9.79)	(−1.05)	(9.2)
S is farm size in acres cropped	−.000033	.00051	−.000012	.0001
	(−5.94)	(11.93)	(−2.74)	(8.50)
W is net worth/acres cropped	.000031	−.002	.000018	−.00007
	(7.65)	(−6.54)	(4.09)	(−7.86)
E is experience	.002	−.0087	.00065	−.0039
	(4.92)	(−2.71)	(1.77)	(−4.2)
R^2	.20	.30	.12	.25

Note: Refer to fourth section for the relationship between the index value and diversification. Summarizing that discussion, M_1 and M_3 decreasing, M_2 and M_4 increasing implies increased diversification.
[a] Indicates farm is located in Fresno County, California.
[b] Indicates farm is located in Madera County, California.
[c] Indicates farm is located in Kern, Merced, San Joaquin, or Tulare County, California.
[d] Indicates whether or not farm is irrigated, $D_4 = 1$, if irrigated.

are more specialized, *ceteris paribus*) for all diversification measures in table 1. These results would be consistent with a decreasing (in wealth) type risk aversion in a cross-sectional sense. That is, wealthier farms are less risk averse and less diversified—other things equal.

Another surprising result concerns the experience variable. Table 1 indicates that younger or less experienced farmers are more specialized. One might speculate that younger farmers are less risk-averse. But, more plausibly, young farmers may start small and specialized and perhaps become more diversified as they expand their operation. This may be indicative of capital shortages for young farmers. Also, it may be difficult for less experienced farmers to manage diverse activities.

Concluding the discussion of results from table 1, "significance" levels vary with the measure of diversification for the organizational dummies. Further, the signs among the different measures are not consistent. However, the evidence suggests that corporate farms are more specialized than other farms.[6]

Table 2 presents results for measures M_1, M_3, and M_4, when these measures are defined over net revenue (M_2 remains unchanged). Net revenue is defined as sales less variable costs. Here it is noted that all "significance" levels are low for variables representing organizational form. This is in contrast to evidence presented in table 1. However, again there is strong evidence that larger farms are more diversified than smaller farms (*ceteris paribus*). Again, the results indicate that more experienced farmers are more diversified than those with less experience, and wealthier farmers are more specialized (*ceteris paribus*). Therefore, on the basis of this sample, evidence suggests that the results stated above are fairly robust with respect to the diversification measure used.

Summary and Conclusions

Using alternative measures of diversification, a sample of California farms revealed evidence that

[6] The rankings in terms of diversification are M_1: $Z_3 < Z_2 > Z_1$; M_2: $Z_3 < Z_2 < Z_1$; M_3: $Z_3 < Z_2 > Z_1$; M_4: $Z_3 < Z_1 < Z_2$, where the Z's represent the sum of the estimated constant plus the dummy coefficient.

analyses of diversification. A priori, one cannot expect the various measures to yield identical results.

Define A_i as the crop acreage in activity i, and ΣA_i as total farm acreage cropped; and let $p_i = A_i / \sum_{i=1}^{N} A_i$ denote proportions. Then the following measures are considered (White and Irwin, Berry, Hackbart and Anderson).

$M_1 = \max_i p_i$ (index of maximum proportion);

$M_2 = \sum_{i=1}^{N} I(p_i)$, (number of enterprises);

where I denotes a zero-one indicator.

$M_3 = \sum_{i=1}^{N} p_i^2$ (Herfindahl index);

$M_4 = \sum_{i=1}^{N} p_i \log \frac{1}{p_i}$ (entropy index).

When M_1 through M_4 are defined for net income, p_i is the proportion of income from crop i. All measures except M_2 can be computed such that they are bounded by zero and one. For increasing diversification, M_1 is generally decreasing, M_2 is increasing, M_3 is decreasing, and M_4 is increasing. This statement is apparent for M_1 and M_2. For M_3 and M_4 (see Berry, Hackbart and Anderson, or Theil).

We shall comment briefly on some of the properties of the measures M_3 and M_4. The Herfindahl index takes a value of 1 when there is complete specialization and approaches 0 as N gets large. That is, if diversification is "perfect," such that

$$A_i = \frac{1}{N} A \text{ and } N \to \infty, \text{ the } \sum_{i=1}^{N} p_i^2 = \frac{1}{N} \to 0.$$

The M_4 is the entropy measure popularized in economics by Theil. It possesses several desirable properties (see Hackbart and Anderson). For our purposes, it is important to note that M_4 approaches its maximum when $p_i = \frac{1}{N}$, or when diversification is "perfect." Recalling Samuelson's theorem, the entropy index is maximized when optimal diversification is undertaken by a risk averter when returns are independent and have equal means. It approaches zero when a farm is specialized.

The Empirical Model

On the basis of theory, one can derive few (if any) firm hypotheses regarding diversification, scale, constraints, organizational form, and other relevant factors. The essential point is that the theory does suggest that these could be important elements in diversification decisions. As limited by our sample, we shall investigate the following relationship:

$$\begin{aligned} M_{jt} = a_0^j + a_1^j \mathbf{Z}_t + a_2^j \mathbf{D}_t + a_3^j S_t \qquad & t = 1 \ldots T \\ + a_4^j W_t + a_5^j E_t + \epsilon_t \qquad & j = 1 \ldots 4, \\ \epsilon_t \sim N(0, \sigma^2), E(\epsilon_t \epsilon_{t'}) = 0 \text{ for } t \neq t', & \end{aligned}$$

where M_{jt} is the jth diversification measure on the tth farm, $\mathbf{Z}_t$ is a vector representing organizational forms (dummy variables for partnership, family corporation, and corporation; family farms are represented by the constant term). $\mathbf{D}_t$ is a vector of locational dummies; S_t (farm size) is acres cropped; W_t (wealth) is net worth per acres cropped; and E_t (experience) is the year the farmer started farming.[3]

The sample consists of data obtained from financial institutions on over 1,000 crop farms in the San Joaquin Valley in California. Most of these farms are not monocultures, and the potential to grow a number of crops is great.[4] This area seems well-suited for the study. We note that we know of few other large microsamples that would allow one to investigate the above relationships (it is particularly difficult to obtain net worth figures).

The Empirical Results

The regression results via ordinary least squares for the four measures computed on crop acreages are given in table 1.[5] At once it is clear that various null hypotheses on the coefficients may be sensitive to the measure of diversification used. However, all of the results suggest that farm size has a positive effect on diversification. This is in contrast to the meager and/or inconclusive evidence computed from the U.S. census by White and Irwin. These results shed some light on the nature of the trade-offs between scale economies and risk reduction mentioned above. That is, if there are large-scale economies in an enterprise, then one might expect larger farms to be more specialized. Clearly our results refute this hypothesis.

The net worth variable shows a significant negative effect on diversification (i.e., wealthier farms

[3] Assets are measured at current market value. Net worth is then calculated as assets minus liabilities. These calculations include all assets (including nonfarm) and all liabilities for each entrepreneur.

[4] Though there is some opportunity for complementary land-use cropping patterns, it is almost always the case that farms have a choice between crop patterns of varying degrees of complementarity. Not only do complementary cropping patterns (e.g., spring and fall vegetables) affect risk but they also reduce cash flow problems. Thus, increased liquid reserves may serve to reduce diversification.

[5] Because most of the diversification measures are bounded by zero and one, one may be suspicious of the assumption of normality. Further, one may wish an estimator which ensures that predicted values of M_j are in the interval (0, 1). A popular transformation to alleviate these problems is the logit transformation (Theil) where the dependent variable becomes $\ln[M_j/(1 - M_j)]$. However, such transformations are used for M_j in the open positive unit interval. Here, $M_j = 1$ is not only possible, but occurs more than 100 times in the data. Hence, ordinary least squares estimators will be presented.

relationship. It also is determined that there is a "significant" negative relationship between diversification and measures of financial "well-being." Finally and somewhat unexpectedly, farmer experience or age exhibits a positive effect on diversification (*ceteris paribus*). That is, younger or less experienced farmers are less diversified.

Theoretical Considerations

Certainty theory gives little explicit insight as to predicted diversification patterns unless three facts are known: (*a*) the nature of the production possibility curve, (*b*) the nature of constraints on firm choice, and (*c*) the prices of inputs and outputs. However, it is well known that increasing returns to scale may promote specialization by reducing the concavity of the transformation surface—or making it convex (White and Irwin).

When uncertainty is introduced, the model becomes more complex and diversification is usually promoted if the decision maker is risk-averse and the covariance of enterprise returns is zero or negative. For later reference, we shall state briefly the results of several theorems assuming stochastic linear technology and risk aversion.

The basic theorem is that if returns in two activities are independently and identically distributed, then diversification is optimal with equal proportions in each activity (Samuelson). Hadar and Russell have generalized Samuelson's results for a number of cases. The result of interest here is that diversification (not necessarily equal proportions) is optimal when returns have equal means but covariances are negative. These results suggest that diversification is likely to be optimal for a risk averter. However, large positive covariances, large disparities in mean returns (e.g., scale economies) or resource constraints may provide incentives for specialization. For example, assuming independence of returns, it can be shown that under risk aversion, optimal production levels of crop activities are found by weighing marginal increases in expected profits against marginal increases in risk (variance). Further, as farm size increases, all activity levels increase if there are sufficient increases in the marginal expected return with respect to the marginal increases in variance. (Therefore, if diversification were measured by the number of active enterprises, diversification would increase with size.) These results emphasize the potentially crucial nature of the trade-off between scale economies and benefits from diversification.

Aside from farm size, a number of potentially interesting variables may affect diversification choices. These include net worth, experience of the farm operator, form of ownership (e.g., family farm, corporation), and dummy variables which delineate the activity choice set (primarily variables that indicate geographical location and the extent of irrigation). Net worth, experience, and organizational form may be rationalized to affect diversification in a risk-preference framework as well as alternative models of behavior. For example, learning by doing may lead to incentives for specialization or, greater experience may change risk preferences. Also, one might expect wealthier farmers to be less risk-averse, if the concept of decreasing risk aversion is applied in a cross-sectional sense, and perhaps less diversified (Markowitz).

Scalar Measures of Diversification

Because the primary purpose of this study is to conduct an inductive inquiry concerning diversification and the above socioeconomic variables in a cross-section of crop farms, it is now necessary to become more precise regarding measures of diversification. Because of data limitations, it is necessary to restrict the indices to include only on-farm agricultural production activities.[2] Two measures typically used are the number of crops grown and the maximum over-crop proportions of sales of a particular crop (see White and Irwin). For the cross-sectional analysis, it is argued that both net income and crop acreages are potentially interesting variables over which to define diversification. The disparity between these two approaches can be illustrated with two examples. If a farm grew 10 acres of strawberries and 1,000 acres of wheat, with each activity yielding $50,000 net income, then clearly, for many uses, acreage proportions may be a deficient measure of diversification. Similarly, suppose a farm grew 505 acres of wheat and 505 acres of tomatoes; yet, due to random forces, income on tomatoes was $5,000 and income on wheat production was $100,000. In such case, income proportions may be a poor measure of diversification (see also Gardner and Pope).

A great deal of research on diversification has been directed toward single-valued measures. However, when a vector of information is collapsed into a scalar, problems can arise (see, for instance, Scherer, pp. 67–69). Clearly, the propriety of a diversification measure depends on the nature of the problem studied. A central question posed here is, "Are larger farms more specialized than smaller farms and is there a systematic relationship between diversification and other farm characteristics?" The approach taken is to utilize a wide variety of diversification measures in order to ascertain if the answer to this question is robust to the diversification measure used. Hence, four measures of diversification are considered: each has desirable properties and is defined over net income and acreage proportions and has been used in empirical

[2] Roughly speaking, the farm in this study is defined legally. If a limited partnership held farming enterprises in three locations, these would be listed as a single farm; similarly for corporate interests. However, when the farming enterprises are not in the general study area, they are excluded in the farm definition and its associated acreages.

Diversification in Relation to Farm Size and Other Socioeconomic Characteristics

Rulon D. Pope and Richard Prescott

Interest by agricultural economists in farm diversification is evident in published research. Since the early work of Markowitz and Heady, attention has focused mainly on mean-variance portfolio approaches (Johnson; Stovall; Carter and Dean; Greve, Plaxico, Lagrone). These studies generally focus on the normative issue of optimal diversification under uncertainty. In the present paper, a positive examination of diversification using detailed microdata is undertaken.

There are several fundamental reasons why diversification may be of interest. First, the relationship between diversification and farm size is an indicator of trade-offs between risk reduction and possible economies of size in a particular activity. That is, if there are substantial economies of scale in a particular activity, one clearly gives up a large expected return in order to insure against risk through diversification. Second, there is policy interest in promoting diversified small farms. In a recent paper prepared for the Congress by the Congressional Budget Office (*Public Policy and the Changing Structure of American Agriculture*), several policy tools were proposed to "discourage the expansion of family-size farms into larger-than-family-size farms" (p. 63). Two such proposals which are particularly relevant here are as follows.

(*a*) "Commodity program benefits could be targeted to small, diversified farms. This could be accomplished by gearing program payments to farm size or existing ownership patterns, and by requiring two or three enterprises per farm for program eligibility" (p. 63).

(*b*) "Public research and information could be aimed exclusively at small and part-time farmers. Diversified farming, labor-intensive production practices, organic farming, and direct marketing would be key research topics" (p. 64). The implication appears to be that a negative correlation exists between size and diversification.

Finally, the relationship between diversification and the form of ownership, wealth, and other variables of interest has policy significance as well. For example, it is of interest to determine whether corporations are more specialized because of the risk-spreading nature of the corporate form of ownership.

Among the most prominent and recent studies of diversification and size is that by White and Irwin. Using aggregate U.S. Census data and comparing diversification across farm classes, they conclude that "Census data have suggested some connection between size and specialization in the past" (p. 210). Generally, the data suggested that larger farms are more specialized, but the data are not conclusive for all farm types and classes. Furthermore, the measure of diversification used was "Sales of Primary Product as a Percent of Total Sales by Farm Class" (pp. 196–7).[1] Given the level of aggregation and the rough measure of diversification used, it would seem beneficial to further study diversification at the microlevel.

The purpose of this paper is to examine the relationship between farm size and other socioeconomic variables and diversification in a large cross-section of California crop farms. As in the White and Irwin study, the diversification measures are limited to farm production activities and do not include income from nonfarm sources or other farm sources such as custom hire. Though some information is available from the Census regarding the general nature of the relationship between farm and off-farm income, it seems as though less is known regarding off-farm or "other" activities as compared to farm production activities. However, it is known that smaller farms generally have a larger proportion of their income from nonfarm sources (U.S. Department of Agriculture). This is particularly true of farms with less than $40,000 of sales. Although a majority of farms in our sample exceed this figure, it is not known how much income is derived from various other sources and how this income may vary with farm size and other variables of interest. Given this limitation of the data employed here, diversification in production is examined using measurements on both net income and acreage.

Contrary to earlier research findings, it is found that, using any of four measures of diversification considered, there is a strong indication of a positive relationship between diversification and size. Further, some evidence suggests that the form of ownership and diversification exhibit a "significant"

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The views expressed in this note should not be attributed to the USDA.

[1] Primary product includes broad crop classifications, e.g., cash-grain, cotton, vegetable, fruit and nut, poultry, dairy, livestock, and other field crops.

risk premiums of farm and nonfarm investors are influenced by tax, credit, and farm policies, and resulting implications for farm size, ownership, and control (Raup, Carter and Johnston).

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References

Carter, H. O., and W. E. Johnston. "Some Forces Affecting the Changing Structure, Organization, and Control of American Agriculture." *Amer. J. Agr. Econ.* 60(1978):738–48.

Federal Reserve Board of Governors. *Federal Reserve Bulletin*. Washington, D.C., selected issues.

———. *Flow of Funds Accounts*. Washington, D.C., 1946–75, and selected quarterly issues.

Jensen, M. C. *Studies in the Theory of Capital Markets*. New York: Praeger Publishers, 1972.

Kmenta, J. *Elements of Econometrics*. New York: Macmillan Co., 1971.

Kost, W. E. "Rates of Return for Farm Real Estate and Common Stock." *Amer. J. Agr. Econ.* 50 (1968):213–24.

Levy, H. "Equilibrium in an Imperfect Market: A Constraint on the Number of Securities in the Portfolio." *Amer. Econ. Rev.* 68(1978):643–58.

Lintner, J. "Inflation and Security Returns." *J. Finance* 30(1975):259–80.

———. "The Valuation of Risk Assets and the Selection of Risky Investments in Stock Portfolios and Capital Budgets." *Rev. Econ. and Statist.* 47(1965):13–37.

Modigliani, F., and G. A. Pogue. "An Introduction to Risk and Return." *Finance. Analysts J.* 30 (March-April 1974), pp. 68–80 and (May-June 1974), pp. 69–86.

Raup, P. M. "Some Questions of Value and Scale in American Agriculture." *Amer. J. Agr. Econ.* 60 (1978):303–8.

Ross, S. A. "The Current Status of the Capital Asset Pricing Model." *J. Finance* 33(1978):885–902.

Sharpe, W. F. "Capital Asset Prices: A Theory of Market Equilibrium under Conditions of Risk." *J. Finance* 19(1964):425–42.

———. *Investments*. Englewood Cliffs, N.J.: Prentice-Hall, 1978.

Standard and Poors. *Trade and Securities Statistics*. New York, selected annual and monthly issues.

U.S. Department of Agriculture. *The Balance Sheet of the Farming Sector*. Washington, D.C., ESCS, selected annual issues.

———. *Farm Real Estate Market Developments*. Washington, D.C., ESCS, selected annual issues.

———. *State Farm Income Statistics*. Washington, D.C., selected annual issues.

U.S. Department of Commerce, Bureau of Economic Analysis. *Survey of Current Business*. Washington, D.C., selected monthly issues.

Table 2. CAPM Results

	Alpha (α)			Beta (β)						
	Value	t	Standard Error	Value	t	Standard Error	R^2	Standard Error Reg.	Durbin-Watson	Rho
National	4.78	2.53*[a]	1.89	.19	1.70	.11	.26	4.97	1.82	.09
Pacific	5.82	5.35*	1.09	.14	1.75	.08	.29	3.50	2.26	−.13
Northeast	7.62	4.25*	1.79	.10	.92	.11	.20	4.86	1.85	.08
Corn Belt	4.67	1.34	3.49	.29	1.80	.16	.32	7.53	1.86	.07
Great Plains	4.24	1.27	3.34	.10	.71	.14	.34	6.85	1.56	.22
Mountain	5.16	3.62*	1.43	.10	.93	.11	.15	4.57	2.16	−.08
Southern Plains	3.91	3.56*	1.10	.23	2.01	.11	.13	4.90	2.26	−.13
Lake	4.69	1.69	2.78	.17	1.36	.13	.36	5.75	1.79	.10
Delta	5.42	3.80*	1.43	.24	1.99	.12	.19	4.53	1.84	.08
Southeast	7.19	4.08*	1.76	.14	1.00	.14	.08	6.19	1.98	.01
Appalachia	4.72	2.77*	1.70	.16	.99	.16	.04	6.76	2.09	−.04

[a] Asterisk denotes significance at the .01 level.

region to .36 in the Lake region. While the R^2 values appear rather low, they generally are consistent with values reported elsewhere for individual securities (Sharpe 1978, Modigliani and Pogue).

Implications and Limitations

The low beta values imply that investment in farm real estate at national or regional levels contributes little systematic risk to a well-diversified portfolio. The remaining nonsystematic risk that is attributed to unique supply and demand conditions of agriculture largely could be eliminated by effective diversification. Resulting rates of return required to hold a claim on U.S. farm real estate in a well-diversified portfolio of stocks and bonds are only slightly above the rate on an asset like nine- to twelve-month government securities. For example, the risk premium required for a claim on farm real estate at the national level given a beta of .19, a risk-free rate of 8% and an expected rate on the market portfolio of 12%, is 0.76% = .19 (.12 − .08). The required return then is 8.76%. The highest regional risk premium (1.16%) occurs in the Corn Belt, with the highest beta value.

Besides the low-systematic risk, positive alpha values imply that farm real estate has offered substantial premiums above those for systematic risk. Hence, for this historic period, returns data, and market index, investments in farm real estate by well-diversified investors appeared to outperform the market and most individual assets too.

Evaluating these CAPM results involves how well the CAPM assumptions correspond to the characteristics of farm real estate investors and markets, and how well the results accord with intuitive judgments about risk and return from farmland. Impacts of inflation are especially perplexing and not well-developed in CAPM analyses. For example, a possible reason for low beta values on farm real estate is greater unanticipated inflation in the latter part of the sample period. Following evidence cited by Lintner (1975), in periods of a year or less unanticipated inflation may lower returns to stocks and bonds, while raising returns to farmland. Moreover, if investors in farm real estate correctly anticipated the inflationary increases in farm returns, then the own-variance and CAPM risk measures reported here are overestimated because of the CAPM's failure to reflect this expectations phenomenon. Risk associated with farm real estate investments would then be related to variance about the anticipations rather than about actual values. How returns for real estate, stocks, and bonds respond to inflation and the implications for risk modeling are important areas needing further study.

Real estate generally is considered a relatively illiquid asset caused by high transactions costs, tax obligations, indivisibilities, and thin markets with less than 5% of total farmland changing hands annually. Hence, the CAPM's failure to account for these effects may bias upwards the resulting returns to farmland. Farmers also are not considered well-diversified with farm ownership resting heavily in rural areas (USDA). Hence, following Levy about the effects of limited diversification, these CAPM results for farm real estate may understate the true beta values and overstate the true alpha values. Finally, the historic analysis raises numerous concerns about effects of data quality, aggregation levels, and imputation of returns to unpaid farming resources.

Despite these shortcomings, the CAPM offers reasonable evidence that farm real estate has low risk relative to other assets and is a promising candidate for risk reduction in well-diversified portfolios. Moreover, the CAPM systematically treats risk pricing in an equilibrium framework that, in turn, yields important insights about the effects of investor behavior and market characteristics. It also broadens the framework for evaluating how

Table 1. Summary Statistics for Rates of Return on Farm Real Estate and the Market Indexes

	Value Return			Production Return			Excess Return		
Model	Mean	S.D.[a]	C.V.[b]	Mean	S.D.[a]	C.V.[b]	Mean	S.D.[a]	C.V.[b]
	--------(%)--------			--------(%)--------			--------(%)--------		
Farm real estate									
National	7.70	5.50	.71	3.06	1.72	.56	6.60	6.31	.95
Pacific	6.18	3.47	.56	5.39	2.19	.41	7.41	5.30	.72
Northeast	8.42	5.83	.69	4.50	2.36	.52	8.76	5.64	.64
Corn Belt	8.50	8.70	1.02	2.71	2.12	.78	7.05	9.44	1.34
Great Plains	7.32	7.18	.98	3.10	2.48	.80	6.26	8.66	1.38
Mountain	7.28	5.41	.74	3.44	1.63	.47	6.56	5.97	.91
Southern Plains	7.36	5.29	.72	2.50	1.60	.64	5.70	6.50	1.14
Lake	7.91	6.94	.88	2.76	2.23	.81	6.51	7.51	1.15
Delta	7.99	4.16	.52	3.40	2.34	.69	7.23	5.69	.79
Southeast	8.69	5.24	.60	3.90	2.19	.56	8.43	6.64	.79
Appalachia	7.53	6.45	.86	2.53	1.99	.78	5.90	7.09	1.20
Market index									
Stock, bond and farm real estate	5.04	9.49	1.88	3.86	1.14	.30	4.74	8.67	1.83
Stock	7.65	12.90	1.69	3.94	1.02	.26	7.44	14.42	1.94
Stock and bond	4.44	10.33	2.33	4.03	1.01	.25	4.31	10.33	2.40

[a] Standard deviation.
[b] Coefficient of variation.

viations were calculated from the annual time series of each measure.

Among regions, the mean excess return ranged from 5.70% in the Southern Plains to 8.76% in the Northeast. The Southeast also exhibited a high mean rate of return while relatively low rates of return occurred in the Appalachian and Great Plains regions. Coefficients of variation for excess returns were highest in the Corn Belt, Great Plains, and Appalachian regions and lowest in the Pacific and Northeast regions.

The excess rate of return on the stock, bond, and farm real estate index averaged 4.74% over the period with a standard deviation of 8.67, giving a relatively high coefficient of variation of 1.83. Mean excess rates of return for the stock and stock-bond indexes alone are 7.44% and 4.31%, respectively, with standard deviations of 14.42 and 10.33. Hence, based solely on their own standard deviations relative to mean returns, farm real estate exhibits lower variation relative to mean returns than does the market index and its stock and bond components. Kost obtained similar results for the stock index using an earlier time period. Moreover, the higher variation for the market index arises from the greater variation in annual change in value. For example, the coefficient of variation for the value-return to the market index (1.88) is much greater than the coefficient for farm real estate (.71) at the national level and for all regions. In contrast, the "production return" on the market index and its components has a higher mean and lower standard deviation than does farm real estate at national and regional levels.

Initial regression results for the CAPM using equation (3) have Durbin-Watson values falling below the lower boundaries and high first-order correlation coefficients among successive disturbances. As a result, regressions were reestimated using the Cochrane-Orcutt iterative method (Kmenta, p. 287). Results in table 2 for the national model show a beta value of .19 for farm real estate which is not significantly different from zero at the .01 level. Results for regional models also indicate consistently low beta values ranging from .10 in the Northeast, Great Plains, and Mountain regions to .29 in the Corn Belt. None of the beta estimates differ significantly from zero. However, standard errors are relatively high and sample values of confidence intervals are relatively wide, so that the sample estimates leave much uncertainty about values of beta. This may be due in part to the relatively small sample size, although the data period already is rather long. Still, beta values appear to fall in the zero to .5 range, which makes them comparable to betas for long-term bonds and lower than betas for most common stocks which fall in the .5 to 1.5 range (Sharpe 1978). Moreover, betas calculated from annual returns likely are less than those calculated from monthly returns, as usually occurs for common stocks, perhaps because annual periods give more time for nonsystematic effects.

The national model shows an alpha value of 4.78, which differs significantly from zero. Alpha values also are high in all regions, ranging from 3.91 in the Southern Plains to 7.62 in the Northeast. Only the Corn Belt, Great Plains, and Lake regions show values that do not differ significantly from zero, although they still are relatively high. An R^2 of .26 for the national model, which differs insignificantly from zero, indicates that about 26% of the variation in national farm real estate returns is associated with changes in returns of the market index. Values of R^2 range from a low of .04 in the Appalachian

Data and Estimation Procedures

Risk premiums on farm real estate are estimated by regressing a time series of excess annual rates of return on farm real estate against excess annual rates of return of a market portfolio. The 1950 through 1977 period is free of dominating events like World War II and the Great Depression. The risk-free asset is investment in nine- to twelve-month U.S. government securities with average annual yields obtained from the *Federal Reserve Bulletin*.

In principle, the market portfolio contains values of all assets that contribute to wealth. Because the true market portfolio and its rate of earnings are virtually impossible to measure, CAPM applications use various indexes as market proxies. The index used here is a combined stock, bond, and farm real estate index with annual returns to each asset weighted by their outstanding market values in each year. The stock index is the widely known Standard and Poors 500, a value-weighted average of 500 stocks, mostly traded on the New York stock exchange. Annual rates of return are measured as the sum of the annual dividend rate on the Standard and Poors (SPP) index, plus the annual percentage change in value of the index.

Annual holding period yields for three types of bonds are measured using price indexes for corporate bonds (industrial, utility, and railroad), domestic municipal bonds, and taxable U.S. Treasury bonds as the sum of (*a*) the coupon rate for each bond index divided by the beginning-of-year bond price, and (*b*) the annual percentage change in value of each bond's price index as reported in the *Survey of Current Business* (U.S. Department of Commerce) and *Trade and Securities Index* (SPP). The measure of annual returns to farm real estate at the national level for use in the index is described below. Annual outstanding values used as weights in forming the stock and bond portion of the market index were obtained from flow of funds data reported by the Federal Reserve Board of Governors, and farm real estate values were from the U.S. Department of Agriculture's (USDA) *Balance Sheet of the Farming Sector*.[2]

Annual rates of return on farm real estate are estimated at the continental U.S. level and for ten farm production regions used in *Farm Real Estate Market Developments* (USDA). Those levels of aggregation are used because data are available and for regional comparisons. Annual rates of return are the sum of annual percentage changes in the index of farm real estate values (1 February) per acre plus annual rates of return to land from farm production.

For the national model, annual percentage changes in the index of farm real estate values are obtained from selected issues of *Farm Real Estate Market Developments*. For regional models, annual percentage changes of farm real estate values are estimated by deriving a weighted average of individual state index values, using each state's value of land and buildings as weights. These indexes primarily reflect changes in real estate values, although annual improvements are included too.

Annual rates of return from farm production result from dividing an estimate of returns to farm real estate in each year by the beginning-of-year (1 January) farm real estate value as reported in the *Balance Sheet of the Farming Sector*. Annual returns to farm real estate are estimated with an approach formerly used by USDA. This approach first estimates net income from production as total net income of farm operators from farming plus cash wages and perquisites of hired labor, interest on real estate and non-real estate debt, and net rent to landlords, minus the imputed portion of rental value of farm dwellings. Net income from farm production then is reduced by imputed returns to total farm labor, management, and non-real estate assets to yield a residual return to farm real estate. Annual returns to non-real estate assets are estimated as the sum of interest paid on non-real estate debt and opportunity costs on equity in non-real estate assets charged at the three-month U.S. Treasury Bill rate.[3]

For the regional models, estimates of annual net income from production were obtained by summing individual state data taken from *State Farm Income Statistics* (USDA). Because no state estimates of imputed returns to labor, management, and non-real estate assets are available, regional estimates reflect proration of national figures among regions in proportion to their contribution of net income from production to the national total.

Results

Results first are reported as means, standard deviations, and coefficients of variation for various return measures for farm real estate and the market index during the 1950–77 period, and then as estimates of beta values and other regression measures for the CAPM. Results in table 1 indicate that the mean annual excess rate of return on farm real estate at the national level over the time period was 6.60%, with a standard deviation of 6.31. This excess return measure is the sum of the annual change in the index of farm real estate values (7.70%) plus the mean annual rate of return to real estate from production (3.06%) less the mean annual rate of return on the risk-free asset (4.16%). Standard de-

[2] Averages of annual weights for each type of asset in the market index during the 1950 to 1977 period are stocks 54.8%, corporate bonds 10.6%, municipal bonds 8.5%, U.S. Treasury bonds 8.2%, and farm real estate 17.8%. The annual proportion of Treasury bonds declined through the period while proportions of corporate and municipal bonds increased. The proportion of farm real estate was higher in early and later years of the period.

[3] This imputation procedure ignores any risk premium on equity in non-real estate assets which likely understates their returns and overstates resulting returns to farm real estate.

Capital Asset Pricing and Farm Real Estate

Peter J. Barry

Increasing interest in and policy concerns about agricultural investments by nonfarm investors, especially in farm real estate, and consideration by trust firms and other investment companies of mechanisms for channeling outside equity capital into agriculture make it important to evaluate agriculture's risk-return characteristics relative to those of other investments. Accordingly, this paper uses the capital asset pricing model (CAPM) to estimate risk premiums required to hold farm real estate in a well-diversified market portfolio. Risk premiums are estimated for farm real estate at the national level and for ten farm production regions of the United States. CAPM results then are evaluated in light of farm real estate's unique characteristics.

Capital Asset Pricing Model

As originated by Sharpe (1964) and Lintner (1965), the CAPM shows that equilibrium rates of return on individual assets adjust to levels that reflect the risk which each asset contributes to a market portfolio of all assets. Investors holding such portfolios need only require compensation for the total market, or systematic, risk that is common to all assets in the portfolio and that cannot be diversified. Consequently, premiums ascribed to individual assets need only compensate for their systematic risk.

In market equilibrium the CAPM expresses the relationship between an asset's expected return and its systematic risk in a linear fashion as the sum of a risk-free rate and a risk premium reflecting the product of the price and quantity of risk:

$$R_j = i + \left[\frac{E(R_m) - i}{\sigma_m^2}\right] c\sigma_m\sigma_j, \tag{1}$$

where R_j is the expected return of asset j, i is a risk-free interest rate, $E(R_m)$ and σ_m^2 are the expected return and variance, respectively, of a market portfolio, and $c\sigma_m\sigma_j$ is the covariance of returns between asset j and the market portfolio, with σ_j as the standard deviation of returns for asset j and c as the correlation coefficient.

In empirical analysis, the model is modified to the familiar beta (β) approach:

$$R_j - i = [E(R_m) - i]\beta_j, \tag{2}$$

where $\beta_j = (c\sigma_m\sigma_j)/\sigma_m^2$. Now excess returns (above i) on asset j are expressed as a function of excess returns on the market portfolio where β_j measures asset j's systematic risk.[1] In the absence of data on expectations, CAPM relationships usually are estimated by regressing a time series of excess returns for individual assets against a time series of excess returns for a market portfolio:

$$R_{jt} = \alpha_j + \beta_j R_{mt} + e_{jt}, \tag{3}$$

where R_{jt} and R_{mt} are excess rates of return on asset j and the market portfolio, respectively, in period t, and e_{jt} is the error term. The anticipated value of alpha is zero, and nonzero estimates imply returns or losses in excess of those needed to compensate for systematic risk.

Proponents of CAPM cite its microfoundations, relative simplicity, and potential testability for a wide range of applications, while skeptics are concerned about the model's restrictive assumptions on characteristics of asset markets and investors. Markets are assumed highly efficient so that expected returns quickly and fully reflect available information; no transaction costs, tax obligations, or indivisibilities exist; and, for risk-free financial assets, lending and borrowing rates are equal. Investors are assumed risk-averse, well-diversified and to hold homogenous expectations that are fully characterized by means and variances over single-period horizons.

Much attention has been given to the CAPM's explanatory capacity and to the consequences of modifying these assumptions (Sharpe 1978, Jensen, Modigliani and Pogue, Ross). Appraisals are mixed, caused, in part, by problems with data and estimation procedures. However, empirical tests appear to support the view that beta is a useful risk measure and that high beta securities are priced to yield high rates of return. Levy also provides important insight into pricing relationships for assets held by relatively few investors who have relatively undiversified portfolios. He shows theoretically that an asset's equilibrium price is determined by a weighted average of the systematic risk it contributes to the portfolios of each of its investors; and that, for undiversified investors, the asset's own variance contributes importantly to this systematic risk relative to its covariance with other assets.

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[1] Systematic risk of asset j equals β_j times σ_m. However, since σ_m is common to all assets, β_j itself shows an asset's systematic risk.

California Coastal Zone Conservation Commission. Environ. Quality Ser. No. 30, Institute of Government Affairs and Institute of Ecology, University of California, Davis, Feb. 1979.

Ministry of Working and Planning, Expert Committee on Compensation and Betterment. "Final Report (Uthwatt)." *Windfalls for Wipeouts*, ed. D. Hagman and D. Misczynski. Chicago: American Society of Planning Officials, 1978.

State Board of Equalization and Assessment. *Adirondack Park Real Property Tax Base Study*. Final Report. New York State, 1978.

Table 2. Percentage Rates of Yearly Price Appreciation by Land Use Classification within the Adirondack Park

Year	Hamlet	Moderate Intensity	Low Intensity	Rural Land	Resource Management
1950–54	1.9	15.7	18.6	4.2[b]	−6.8[b]
1955–59	−1.3	−5.0	−2.7		
1960–64	2.9	8.0	−2.6	6.5[b]	7.4[b]
1965–69	6.3**[a]	9.7*	10.0[b]		
1970	10.4	22.4	3.9	52.9	−12.7
1971	16.2	28.3	15.5	−15.1	56.2
1972	−14.0	−15.3	−11.1	−8.1	6.3
1973	81.5	34.7*	76.1*	135.5**	20.8
1974	−10.7	27.2	−7.1	−59.6**	133.9
1975	4.0	−20.7	−6.8	14.2	−68.4
1970–72	3.3	9.9	2.2	6.1	13.2
1973–75	19.0	10.7	15.1	2.8	−3.7

[a] The significance of the individual yearly percentage rates of price appreciation was determined by applying a T-test to the corresponding coefficient estimates; * by a yearly estimate indicates that it is significantly different from zero at the 5% level; ** indicates that the estimate is significant at the 10% level.

[b] The numbers listed here reflect the average percentage rate of price appreciation over the decade.

did plan on intensive development, their properties would have a lesser value to prospective buyers. For other parcels, the Plan indicated land uses and intensities that were more flexible relative to current and expected development expectations. If these direct impacts were all that influence values, the resultant changes in property values would be relatively easy to predict. Unfortunately, the real estate market is not so simply analyzed: properties have values not only from direct uses but also from the enjoyment of neighborhood amenities. If the Plan could protect these amenities by preventing some of the adverse impacts of future development, land values in the park could have been enhanced. Thus, one could reasonably anticipate several separate forces resulting from enactment of the Plan. Some forces acted to shift relative values of properties classified into different use categories, while others acted on entire neighborhoods within the park. Some forces even may have acted on the park as a whole, shifting values there relative to values in adjoining areas.

The empirical evidence marshaled for this study suggests that the Plan did affect relative values for different land use classifications. Following the enactment of the Plan, relative prices for the five nonindustrial, private, land use categories shifted, with the less restrictive classifications showing the better relative price performance.

Land values within the park were largely unaffected relative to those in the out-of-park control area. In-park properties, taken as a whole, were estimated as having risen approximately 4% less per year than the out-of-park sample following the enactment of the Plan, but this is a small difference relative to historical fluctuations in the regional real estate market. Further testing of this conclusion could be obtained by increasing the sample size and by extending the period of analysis into the future. Only with an expanded effort could shifts in relative values of in-park and out-of-park land be definitively measured.

The empirical analysis presented here represents a promising method for evaluating the price impacts of alternative land use schemes. The ability of the technique to show the relative price impacts of land use programs, while holding other price-influencing variables constant, is not just of academic interest, but of a more general importance. Properly used, it can provide answers to questions often asked in the political arena concerning, for example, the equity implications of a zoning program that shifts land from one use classification to another. The measurement of yearly percentage increases in land values can help focus public perceptions and clarify the ultimate impact of land use schemes, thereby becoming a valuable tool for state and local planning officials.

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References

Abelson, P. W. "Property Prices and the Value of Amenities." *J. Environ. Econ. and Manage.* 6(1979):11–28.

Adirondack Park Agency. *Adirondack Park Economic Profile Phase Two: Recent Trends and Factors Affecting the Adirondack Park Real Estate Market.* New York State, Aug. 1976.

Anderson, R. C. "Paintings as an Investment." *Econ. Inquiry* 12(1974):13–26.

Baily, M., R. Muth, and H. Nourse. "A Regression Method for Real Estate Price Index Construction." *J. Amer. Statist. Assoc.* 58(1963):933–42.

Kneisel, R. *Economic Impacts of Land Use Control: The*

assessors were used to identify properties for which significant improvements had been made in physical structures. Improvements to properties also were indicated by excessively high implicit rates of price appreciation over short periods. The rule of thumb used in the latter criterion was that an observation was deleted if the sale price increased 100% during a one-year holding period, 200% during a three-year holding period, and 300% after five years.

Other reasons for dropping observations were: transactions between individuals with the same surname, the prices for which may not reflect the true market values; missing information; and, because property values were trending upward during the period of analysis, observations where the sale price was less than 75% of the purchase price. In total, after deleting observations, there were 471 in-park observations and forty-five out-of-park observations. Of the total in-park observations, 278 were in the hamlet classification; seventy-one in moderate intensity; sixty-seven in low intensity; twenty-seven in rural land; and twenty-eight in resource management.

Table 1. Percentage Rates of Yearly Price Appreciation for Land Transactions within and outside the Adirondack Park

Year	In-Park All	Out-of-Park All
1950–54	6.1**[a]	−5.8[b]
1955–59	−3.4	—
1960–64	4.3*	10.6*[b]
1965–69	6.9*	—
1970	15.9	23.6
1971	13.1	39.3
1972	−9.0	−48.9
1973	65.0*	131.5**
1974	−4.6	−6.9
1975	0.8	−13.9
1976	29.4	—[c]
1970–72	6.0	−4.2
1973–75	18.6	22.9

[a] The significance of the individual yearly percentage rates of price increase was determined by applying a T-test to the corresponding coefficient estimates; * by a yearly estimate indicates that it is significantly different from zero at the 5% level; ** indicates that the estimate is significant at the 10% level.
[b] The numbers listed here reflect the average percentage rate of price appreciation over the decade.
[c] Because of insufficient data the estimate was omitted.

Model Results

The estimated yearly percentage rates of price appreciation for all in-park land, all out-of-park land, and in-park land by land use classification are presented in tables 1 and 2. For all regressions, the years 1950–69 were separated into five-year groups except where the total number of observations was less than sixty, in which case the years 1950–69 were separated into ten-year groups. The statistical significance is indicated for all the regression coefficients.

The wide fluctuations in the out-of-park estimates, due mainly to the small data set, make comparison of in-park and out-of-park land value changes, shown in table 1, difficult. Summary data for the period immediately following the passage of the Plan, 1973–75, show that the sample of in-park properties, taken as a whole, appreciated at the somewhat greater rate of 22.9% per year for the same period. Statistically, however, the difference in rates of appreciation is not significant. One interesting comparison is between the price appreciation in the pre-Plan years, 1970–72, and the post-Plan period, 1973–75. Prices during the former period appreciated more slowly than in the latter period. This may be explained, in part, by the uncertainty surrounding the final outcome of the master plan for management of the Adirondack that was being prepared from 1971 to 1972. While land buyers knew that some form of regulation probably would be imposed on land transactions within the park, they did not know the specifics of the Plan, and may have been hesitant to enter into the market. This dampening of demand for land is a natural result of buyers not wanting to purchase land when the development possibilities for the land are not certain.

Table 2 portrays rates of yearly price change by land use classification within the park. Averages of the point estimates for the years 1970–72 and 1973–75 also are reported. Because of the relatively small sample sizes for some of the land use classifications, these averages should be more representative of actual rates of price change than the individual price estimates. Using these averages, land use groups can be ranked by their price changes subsequent to passage of the Plan. Hamlet parcels showed the greatest relative price increase (19.0%) followed by light intensity (15.1%), moderate intensity (10.7%), rural land (2.8%), and resource management (−3.8%). This ranking tends to provide empirical support for the theoretical impacts predicted earlier—that hamlet land and already existing small parcels should increase the most in relative value. The resource management classification actually showed a decline in value, although the erratic pattern of price behavior makes any interpretation of the estimates for these lands questionable.

Conclusions

That the broad set of land use controls in the Adirondack Park Plan affected expected future land use decisions is certain. Specific properties were severely limited as to potential future uses and development intensity. The owners of many of these parcels no doubt were disappointed, for even if they

measure the appreciation of land values in the park relative to land values outside the park.

The virtue of the methodology described below is that it allows the researcher to hold the sample constant over the period of the analysis. As will be discussed later, this is accomplished by carefully scrutinizing the data before applying them to the regression model. If additional data were available, another technique, hedonic analysis, which has been used to measure the value of environmental benefits as well as the value of different characteristics of land parcels, could have been used (Abelson). The technique described here is useful for its simplicity and can be used when little interest is attached to the value of specific site characteristics.

The Model

The derivation of the regression model for estimating the yearly percentage rates of price appreciation is developed below. Let B_t equal the percentage increase in price during year t, and $U_{itt'}$ equal an error term signifying the amount by which the given observation deviates from the prediction of the rate of price appreciation. The ratio of the final price of property i in year t' to the initial price in year t, $R_{itt'}$, can be expressed as

(1)

$$R_{itt'} = (1 + B_t)\ (1 + B_{t+1})\ .\ .\ .\ (1 + 1B_{t'})\ (U_{itt'}).$$

Taking natural logarithms of (1), gives

$$r_{itt'} = b_t + b_{t+1} + \ .\ .\ .\ + b_{t'} + u_{itt'}, \tag{2}$$

where the lower case letters denote natural logs of the expressions in parentheses on the right-hand side of (1).

Date Exchanged	Price	Date Exchanged	Price	Classification
30 June 1966	2.20	28 April 1976	\$4.50	Hamlet

An equation for estimating $r_{itt'}$, given observations of percentage increases in price and the length of time a parcel was held, can be developed by letting x_t equal 1 if the property was held during year t, a fraction of 1 if it was held for a fraction of year t, and 0 if the property was not held at all during year t. Thus,

$$r_{itt'} = b_t x_t + u_{itt'}. \tag{3}$$

Equation (3) is more readily visualized as a linear equation if expressed in matrix terms.

$$\mathbf{R} = \mathbf{X}B + \mathbf{U}, \tag{4}$$

where $\mathbf{X}$ is a $N \times T$ matrix of observations on the independent variables, the x_t's; $\mathbf{R}$ is a $N \times 1$ vector of observations on the dependent variables, the $r_{itt'}$'s; $\mathbf{B}$ is a $T \times 1$ vector of parameters to be estimated, the b_t's; and $\mathbf{U}$ is a $N \times 1$ vector of disturbance terms, the $u_{itt'}$'s.

Using (4), the ordinary least squares (OLS) estimate, $\mathbf{B^*}$, of the $\mathbf{B}$ matrix is given by

$$\mathbf{b^*} = (\mathbf{X'X})^{-1}\mathbf{X'R}. \tag{5}$$

The estimates of the b_t's contained in the $\mathbf{B^*}$ vector can be found by solving for the yearly rates of price appreciation in (1) by calculating

$$\hat{b}_t = e^{b^*}(t) - 1, \tag{6}$$

where $\hat{b}_t$ is the estimate of the percentage increase in price in period t and the $b^*(t)$ is an individual element in the $\mathbf{B^*}$ vector.

The data required for the application of this model to the assessment of the price impacts of the Plan are pairs of transaction prices for the same parcels of land and the dates of the transaction. To this end, land deeds for five towns with the Adirondack Park and one town outside the park were examined for the years 1950–76, and the appropriate data obtained. The five in-park towns (Cargoa, Webb, Fine, Harrietstown, and Westport) were chosen as a cross-section of the entire park and represent, as closely as possible, five distinct geographical regions in the park (Champlain, High Peak, southeast central, southwest central, and northwest). The out-of-park town (Redfield) is located in the Tug Hill region of New York and was chosen as a comparable resort area. Although the deeds did not contain the actual purchase or sale prices for the parcels, they did contain the tax paid on the transaction, recorded as the value of the tax stamps for the sale or purchase. Because only relative price changes were to be measured, tax stamp information would adequately reflect true relative market prices.[2]

An example of a typical observation is

In the few instances when one parcel changed hands three times within the period of the test years, the transactions were included as two observations.[3]

With the data arranged as above, inconsistent observations were dropped from the data base. Data were deleted if property improvements had been made during the holding period; inclusion of these observations would have violated the assumption of constant quality of the land parcels. Visual inspections and interviews with the town

[2] Because the stamps record only value increments of \$500, use of the stamp data could lead to the overstatement of prices on an unknown number of properties. Depending upon whether the initial, final, or neither price in a pair was overstated, the relative prices on a given observation pair could be understated, overstated, or accurate. This may be interpreted statistically as an error in variables problem in the dependent variable.

[3] As Baily, Muth, and Nourse note, this introduces a slight bias to the estimates.

of potential development options of parcels within the park. By limiting the development alternatives of any particular lot, the Plan, in some cases, also affected the characteristics attributed to adjoining parcels which were not restricted or were less restricted than the controlled areas. For example, such characteristics as view or aesthetics may be enhanced in parcels adjacent to sites where minimum acreage restrictions are in effect.

The direct impact of development size limitations can be hypothesized as almost certainly negative for all but the hamlet use classification (where no site restrictions were imposed) because minimum size guidelines restrict rather than enhance the range of potential development options. With no restrictions, the range of options is greatest and the value of individual development size can be maximized. Relative impacts for different parcels will depend upon the magnitude of the adjustment in development expectations. The indirect impacts of size limitations are not easily diagnosed. Limits on the minimum acreage for development should protect both views and aesthetics derivable from adjoining parcels. In economic terminology, this reduces the likelihood of externalities which might otherwise occur were adjacent property owners free to develop as they see fit.

It should be noted that there are a number of additional complications as to the final effect of land use classifications on site values. In a region where land planning and use control were virtually nonexistent, there is now one of the most comprehensive systems in the country. But land buyers and sellers have little precedent from which to predict the Plan's impact on land values. Developers have little basis for judging the most profitable way of packaging and developing the regulated land. Furthermore, although the partial impact of a single regulatory strategy (e.g., lot size limitations, permits, or grandfather and children's clauses) on a single site characteristic (e.g., view, lot size, etc.) may be predicted reasonably well, the overall combined impact on property values is far less easily determined. Many of the impacts tend to be offsetting and of unknown relative magnitudes. Moreover, the timing of the effects is highly speculative. The Plan introduced a new element of uncertainty into the Adirondack land market, and it may take several years before the participants in the market feel confident that they know how all of the regulations will be interpreted and enforced. As a result, land market values will almost certainly move slowly to new equilibrium levels.

Despite these caveats it is possible to develop some tentative hypotheses concerning the land price impacts of the Plan's land-use intensity guidelines. Among the separate regulations of the Plan, the restrictions on lot size are likely to be the most significant in affecting relative land values between the different land use classes. Based on the previous discussion, the following two hypotheses can be formulated: (*a*) Hamlet land and already existing small parcels should increase the most in relative value as the expected supply of these parcels decreases. (*b*) Relative values for large parcels, particularly in the most restrictive use classifications (such as rural or low intensity land) should fall as development expectations are revised downward. In addition to these hypotheses, it is likely that the value of park land relative to nearby land outside the park would change, especially in the short run. Although no specific hypothesis is developed for this impact, an assessment of its magnitude and direction would be useful.

The remainder of this paper is devoted to an empirical assessment of the actual price impacts, and the extent to which these tentative hypotheses are supported by the evidence.

Price Estimation Methodology

While there have been several previous studies on the economic effects of the Plan that help shed some light on the probable price impacts, these analyses stand on weak methodological grounds and do not provide any information on the relative price impacts among different land use classifications. One of the most glaring problems is the failure to isolate price effects due to the Plan from price effects caused by other influences. For example, the New York State Board of Equalization and Assessment found that during the first eleven months following the enactment of the Plan, average per acre sales prices for parcels of Adirondack land rose at a higher rate than land prices throughout New York State (21.4% vs. 14.8%). Although this finding might suggest that the Plan benefited the Adirondack region relative to the rest of the state, the analysis did not take into account the possibility that average parcel size in the sales and transactions may have changed or that property improvements within the park may have exceeded those outside the park. Both of these factors may have caused prices in the Adirondacks to experience relatively higher rates of increase.

The technique used in this paper is designed to cope, at least partially, with the sort of problems described above, through the use of more detailed information on land values. The intent is to estimate the yearly rates of price appreciation for land located both within and outside the park boundaries using an approach suggested by Anderson for measuring price appreciation for art. For in-park land, separate price series were estimated for parcels in each of five private, residential land use classifications used by the Adirondack Park Agency.[1] By comparing the estimated rates of price appreciation, one can test the hypothesis that land appreciated differently among the five land use categories. In addition, this approach can be used to

[1] Values for lands classified as industrial were not included in the analysis.

Land Price Impacts of the Adirondack Park Land Use and Development Plan

Robert C. Anderson and Roger C. Dower

The enactment of any ambitious land use control system raises a variety of concerns about the effects of the system on land values. Restrictions on allowable use typically are opposed by the affected landowners in that such controls may depress market value. Owners of land not encumbered by controls may be far more sanguine, believing the demand for developable parcels will be enhanced. These concerns are likely to be expressed whenever land use controls are imposed. A particularly strong reaction followed the legislation that created the Adirondack Park Agency in New York State. The 1973 enactment of the Adirondack Land Use and Development Plan by the agency introduced sophisticated land use controls where virtually no regulation on private land had existed previously. One key policy issue that arises is the impact of this new set of controls on property values. The need for empirical answers to this issue is prompted by concerns over the equity of the program. Land value changes determine, in part, who pays and who benefits from the program. This concern is certainly not unique to the Adirondack land use control case, but has been raised in the context of economic evaluation of land use controls in other regions as well (Kneisel).

This paper addresses the issue of land price impacts. Specifically, a technique is described for measuring the price impacts of land use control systems and is applied to the Adirondack Park Land Use and Development Plan.

New York's Adirondack Park contains some six million acres, three-fifths of which are now in private ownership and two-fifths in state ownership. Although efforts to manage this collection of private and public holdings of mountains, lakes, forests, and villages date at least to the creation of the State Forest Commission in the 1800s, a fully comprehensive plan was not enacted until 1973. In that year the Adirondack Land Use and Development Plan (hereinafter referred to as "the Plan") was signed into law. The Plan separated the park into several land use intensity zones. These were, ranging from lowest to highest permitted intensity of development: resource management, rural, low intensity, moderate intensity, hamlet, and industrial. The most critical restriction on residential development is the intensity guideline for each of these classes. In general, moderate intensity land cannot be developed with a density greater than 1.28 acres per house; low intensity land must allow 2.3 acres per house; rural land 8.5 acres per house; and resource management 42.0 acres per house. No intensity guidelines apply in the industrial and hamlet areas.

In addition to the intensity guidelines, the Plan also created a permitting authority for many projects to be exercised by either the park agency or the appropriate local government. Permit authority can be used to veto certain projects, but the more common usage is to impose conditions on development. Typical conditions include architectural standards, erosion control measures, screening and planting requirements, and prevention of view disruption. Another provision of the Plan granted through a "grandfather clause" the rights to develop subdivided but as yet undeveloped parcels. Furthermore, under the "children's clause," owners of large parcels may split off smaller sites for their children.

The following discussion presents a methodology for estimating how such a system of land use intensity controls would affect market values of the different classifications of land. Other regulatory aspects of the Plan will not be addressed except to the extent that they affect the price impacts of the land use intensity provisions.

Estimation of Price Impacts

It is established theoretically that public programs directed at controlling the uses of land tend to shift values within the controlled area as well as lands adjacent to that area (Ministry of Working and Planning). The value of a particular parcel of land is derived from the marketplace valuation of the characteristics that describe the site, such as size, views, access, site flora and fauna, and adjoining ownership. The imposition of a land use control scheme alters buyers' and sellers' expectations concerning individual site characteristics and therefore the value of the land.

The Adirondack Park Plan contracted the range

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Crosson, P. "Demands for Food and Fiber: Implications for Land Use in the United States." *Land Use: Tough Choices for Today's World*. Ankeny, Iowa: Soil Conservation Service of America Spec. Pub. No. 22, 1977.

———. "U.S. Agricultural Production Capacity: Comment." *Amer. J. Agr. Econ.* 60(1978):144–47.

Dideriksen, R. I., A. R. Hidlebaugh, and K. O. Schmude. *Potential Cropland Study*. Washington, D.C.: USDA Soil Conservation Serv. Statist. Bull. No. 578, 1977.

Gardner, B. D. "The Economics of Agricultural Land Preservation." *Amer. J. Agr. Econ.* 59(1977):1027–36.

Hart, J. F. "Urban Encroachment on Rural Areas." *Geographical Rev.* 66(1976):1–17.

Heady, E. O., and J. R. Timmons. "U.S. Land Needs for Meeting Food and Fiber Demands." *J. Soil and Water Conserv.* 30(1975):15–22.

Lee, L. K. "A Perspective on Cropland Availability." Washington, D.C.: USDA ESCS Econ. Rep. No. 406, 1978.

National Academy of Sciences. *Agricultural Production Efficiency*. Washington, D.C., 1975.

Pimentel, D., W. Dritschilo, J. Krummel, and J. Kutzman. "Energy and Land Constraints in Food Protein Production." *Science* 190(1975):754–61.

Pimentel, D., et al. "Land Degradation: Effects on Food and Energy Resources." *Science* 194(1976):149–55.

Plaut, T. "Urban Growth and Agricultural Decline: Problems and Policies." Ph.D. thesis, University of Pennsylvania, 1978.

Schiff, S. D. "Land and Food: Dilemmas in Protecting the Resource Base." *J. Soil and Water Conserv.* 34(1979):54–59.

Schneider, S., with L. E. Mesirow. *The Genesis Strategy: Climate and Global Survival*. New York: Plenum, 1976.

U.S. Department of Agriculture. *Our Land and Water Resources: Current and Prospective Supplies and Uses*. Washington, D.C.: ERS Misc. Pub. No. 1290, 1974.

———. *Agricultural Statistics, 1978*. Washington D.C., 1978a.

———. *Changes in Farm Production and Efficiency, 1977*. ESCS Statist. Bull. No. 612, Washington, D.C., 1978b.

U.S. Department of Agriculture, Soil Conservation Service. *National Inventory of Soil and Water Conservation Needs*, state summaries. Published by the State Conservation Needs Committees in 1970, 1971.

———. "National Summaries of the 1977 *National Resource Inventories*." Washington, D.C., 1979.

U.S. Department of Commerce, Bureau of the Census. "Projections of the Population of the United States: 1977 to 2050." *Population Estimates and Projections*. Washington, D.C.: Series P-25, No. 704, 1977.

U.S. Office of the President. *Economic Report of the President*. Washington, D.C., 1979.

Vining, D. R., T. Plaut, and K. Bieri. "Urban Encroachment on Prime Agricultural Land in the United States." *Int. Reg. Sci. Rev.* 2(1977):143–56.

Yeh, C. V. "Prices, Farm Outputs, and Income Projections under Alternative Assumed Demand and Supply Conditions." *Amer. J. Agr. Econ.* 58(1976):703–11.

Yeh, C. V., L. G. Tweeten, and C. L. Quance. "U.S. Agricultural Production Capacity." *Amer. J. Agr. Econ.* 59(1977):37–48.

rise. High inflation has a clear effect in all projections by shifting the supply curve to the left, and thus decreasing output and increasing prices received. Prices received do not increase as fast as prices paid, however, so real prices fall.

Projections of Future Farmland Needs

Agricultural land needs are defined here in terms of cropland because it is clearly the most productive farmland use. Cropland is used not only for the direct production of food for human consumption, but it also indirectly supports much (if not most) of the United States' meat production.

The output projections in table 3 can be converted to cropland requirements through projections of future agricultural yields. In the optimistic projection, agricultural yields (agricultural output per acre of cropland) are expected to increase at an average annual rate of 1.75% from today to the year 2000, while in the pessimistic projection, agricultural yields are expected to show no increase (from the trends for the 1960s and 1970s, see table 2). In 1977, an agricultural output of 121 was supported by 413,000 acres of cropland (ratio = 0.293), so in the year 2000 the output-to-cropland acre ratio is expected to range from 0.293 (pessimistic projection) to 0.437 (0.358 in the middle range projection).

From table 3, it can be seen that, in the optimistic projection, rapid increases in yields and relatively low output will make it possible to retire about one-third of the present cropland base from production by the year 2000. In the pessimistic projection, however, substantially more cropland will be needed in order to support the large increases in farm output in the years ahead. In the most pessimistic case, the nation will need 154 million acres of additional cropland by the year 2000. This is more than the 135 million acres of potential cropland currently available.

It should be noted, however, that there may be an important limitation in this part of the analysis. In estimating future agricultural yields, it has been assumed implicitly that the present "mix" of agricultural output will be maintained in the future. However, under high demand pressures, it may be possible to shift some cropland away from the indirect to the direct production of food for human use. Such a shift could increase agricultural yields and substantially reduce the possibly high demand pressures on our land resources.

Implications for the Future

Our estimates of cropland needs in the year 2000 delineate a wide range of possible situations. In the optimistic projection, it will be possible to retire up to one-third of the present cropland base from production over the next quarter century, and, in this case, the urbanization of farmland is probably not of national concern. In the pessimistic projection, however, American agriculture may need more additional cropland by 2000 than the 135 million acres of currently available potential cropland. Here, the continued urbanization of farmland could seriously constrain future increases in agricultural production.

Such a wide range of estimates of future cropland needs may not seem particularly useful, but actual conditions probably will fall somewhere in between. And unless the most favorable circumstances prevail, it will be necessary to bring some additional cropland into production to support future agricultural output. The urbanization of farmland serves only to exacerbate this problem, because, in order to expand the cropland base, it is necessary to replace that farmland lost to urbanization plus bring some nonfarmed land into production. Present trends indicate that urban expansion may effectively reduce the present cropland reserve by more than 10% and the present reserve of prime agricultural land by almost one-half by the end of the century.

We do not want to suggest that there will be an absolute shortage of farmland in the future. Clearly, under heavy demands for agricultural output, the price of farmland will be bid up and less productive land will be pushed into agricultural production. However, such a shift will decrease productivity and yields, further increase output prices, and increase erosion and other environmental costs. In addition, continued urbanization is not the only factor affecting future farmland availability. The agricultural land base may be reduced further in the future because of the continuing loss of topsoil to erosion, the depletion of groundwater and surface water supplies in the Southwest, and a possible reduction in the growing season in the northern perimeter of the country due to climatic shifts (Pimentel et al. 1975, 1976).

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References

Barton, G. T., and D. D. Durost. "Measuring Input Changes in Agriculture." *J. Farm Econ.* 42 (1960):1398–1410.

Berry, D. "Idling of Farmland in the Philadelphia Region." Regional Science Research Institute Disc. Pap. Ser. No. 88, Philadelphia, 1976.

———. "Effects of Urbanization on Agricultural Activities." *Growth and Change* 9(1978):2–8.

———. "The Sensitivity of Dairying to Urbanization: A Study of Northeastern Illinois." *Professional Geographer* 31(1979):170–76.

Brubaker, S. "Land—The Far Horizon." *Amer. J. Agr. Econ.* 59(1977):1037–44.

Table 2. Average Annual Changes in Demand and Supply Shifters, 1960/62–1970/72 and 1970/72–1975/77

	1960/62–1970/72	1970/72–1975/77
	(%)	
Demand Shifters		
U.S. population	1.20	0.79
Real per capita disposable income	2.94	1.73
Agricultural exports	3.33	7.37
Supply shifters		
Agricultural productivity	1.66	1.57
Prices paid by farmers	2.92	10.06
Agricultural yields (crop output per cropland acre)	1.83	0.49
Agricultural yields (agricultural output per cropland acre)	1.75	−0.20

Sources: U.S. Office of the President (1979), tables B-22, B-92, B-93; U.S. Department of Agriculture (1978a) table 781; and U.S. Department of Agriculture (1978b) tables 1 and 13.

production, (*c*) a slowdown in technological advances in the agricultural sector and in the mechanization of agriculture, and (*d*) a return to the "usual" more variable weather pattern in the United States (Crosson 1977, National Academy of Sciences, Schneider). It is suspected that the 1967 price weights, which are used to measure the level of farm inputs in the productivity series for the 1970s, may not reflect the relative input prices that have existed in the agricultural sector since the rapid increase in energy prices in 1973. Barton and Durost, for example, have shown that the USDA farm input series is fairly sensitive to shifts in the underlying price weights. It thus appears to be prudent to project future agricultural output with a lower productivity estimate than that indicated by currently published figures. One percent per year seems to be a reasonable lower estimate of future increases in agricultural productivity.

Table 3 shows the results of the optimistic and pessimistic projections and also of a "middle-range" projection where demand and productivity are expected to increase as annual rates of 1.97% and 1.33%, respectively. In the optimistic projection, future agricultural output is expected to remain at about its current level of 121 (1967 = 100), while real prices (prices received divided by prices paid) will decline markedly (from 91 in 1977). In the pessimistic projection, however, agricultural output will increase substantially and real prices will also

Table 3. Alternative Projections of Agricultural Output, Prices, and Cropland Needs in the Year 2000

Scenario	Agricultural Output (1967 = 100)	Agricultural Prices (1967 = 100): Prices Received	Agricultural Prices (1967 = 100): Real Prices (*PR*/*PP*)	Cropland Needs (millions of acres)	Additional Cropland Needs Compared to 1977 (millions of acres)
1. Optimistic projection: demand up 1.17% per year; productivity up 1.66% per year; yields up 1.75% per year:					
Low inflation (4% annually)	127	380	73	291	−122(29.5%)
High inflation (8% annually)	111	739	62	254	−159(38.5%)
2. Pessimistic projection: demand up 2.77% per year; productivity up 1.00% per year; yields up 0.00% per year:					
Low inflation (4% annually)	166	621	120	567	154(37.3%)
High inflation (8% annually)	144	1207	101	492	79(19.1%)
3. Middle range projection: demand up 1.97% per year; productivity up 1.33% per year; yields up 0.88% per year:					
Low inflation (4% annually)	145	486	94	405	−8(1.9%)
High inflation (8% annually)	126	944	79	352	−61(14.8%)

unlikely to be challenged by 1985" (p. 47). This finding, however, has been vigorously challenged by Crosson (1978).

The plan of this part of the paper is simple. First, the NIAP system is used to predict equilibrium levels of farm output and prices in the year 2000 under alternative sets of future conditions. Second, these output predictions are combined with estimates of future agricultural yields in order to estimate future farmland needs.

The NIAP System

The NIAP demand-supply system as presented by Yeh is

(1) Demand: $$\ln Q_{d,t} = \ln\alpha_d + \beta_d \ln PR_t + (1 - \delta_d)\ln Q_{d,t-1} + \delta_d \sum_{t=to}^{t-1} g_{d,t} + g_{d,t};$$

(2) Supply: $$\ln Q_{s,t} = \ln\alpha_s + \beta_s \ln(PR_t/PP_t) + (1 - \delta_s)\ln Q_{s,t-1} + \delta_s \sum_{t=to}^{t-1} g_{s,t} + g_{s,t}; \text{ and}$$

(3) Market Equilibrium: $Q_{d,t} = Q_{s,t}$,

where $Q_{d,t}$ and $Q_{s,t}$ are the quantities of agricultural output demanded and supplied in year t (measured by the USDA index of agricultural output), PR_t is the USDA index of prices received by farmers in year t, PP_t is the USDA index of prices paid by farmers in year t, and $g_{d,t}$ and $g_{s,t}$ are the proportional shifts in demand and supply in year t (due to exogenous factors).

From other studies, Yeh found that the following figures provide reasonable estimates for the parameters in the system: β_d (the short-run elasticity of demand) equal to -0.15, β_s (the short-run elasticity of supply) equal to 0.20, δ_d (the adjustment parameter in demand) equal to 0.70, and δ_s (the adjustment parameter in supply) equal to 0.20.

At this point, it is important to discuss how the exogenous shifts in demand and supply are calculated in these equations. To calculate the annual shift in demand for agricultural products, the following equation is used:

(4)
$$g_{d,t} = (1 - w)[(\Delta p/p) + 0.14\,(\Delta y/y)] + w\,(\Delta E/E),$$

where $\Delta p/p$ is the rate of increase in the U.S. population during the year, $\Delta y/y$ is the rate of increase in real per capita disposable income during the year, 0.14 is the income elasticity of demand for agricultural products at the farm level (from Yeh), $\Delta E/E$ is the rate of increase in agricultural exports during the year, and w is the proportion of agricultural output that is exported. The supply equation, on the other hand, is subject to two exogenous shifts—a shift to the right due to productivity increases in agricultur ($g_{s,t}$) and a shift to the left due to inflationary increases in input prices (prices paid by farmers).

Using the above parameter estimates, equations (1), (2), and (3) were combined in order to find reduced form equations for farm output and prices. These equations were then fit to data for the period 1960–77 to find estimates of the constant terms. Using our constant terms, the mean absolute percentage errors in predicting output and prices during 1960–77 were 2.6% and 7.0%, respectively.

Projections of Future Agricultural Output and Prices

Agricultural output and prices are projected under two sharply different future scenarios: (*a*) a pessimistic projection, which assumes a continuation to the year 2000 of the demand and productivity trends of the 1970s, and (*b*) an optimistic projection, which assumes that there will be a return to the demand and productivity trends of the 1960s in the future. Prices paid by farmers are assumed to increase at a relatively low rate of 4% per year to a relatively high rate of 8% per year in both sets of projections. Increases in input prices are, of course, due to general inflation in the economy, which is assumed to be exogenous to the system.

The future demand and productivity shifts were obtained as follows. Demand is expected to increase from 1.17% to 2.77% per year. The optimistic (low) demand shift is based on average annual increases in (*a*) the U.S. population of 0.55% (from the Census Bureau's Series III population projections), (*b*) real per capita disposable income of 1.73% (the 1970s trend, see table 2), and (*c*) agricultural exports of 3.33% (the 1960s trend, see table 2). The pessimistic (high) demand shift is based on the following average annual increases: (*a*) the U.S. population—1.16% (from the Census Bureau's Series I population projections), (*b*) real per capita disposable income—2.94% (the 1960s trend, see table 2), and (*c*) agricultural exports—7.37% (the 1970s trend, see table 2). The percentage of agricultural output which is exported is expected to range from 14.8% (the average for the 1960s) to 20.6% (the 1970s average).

Agricultural productivity, which shifts the supply curve to the right, is expected to increase from 1.00% to 1.66% in the future. The optimistic (high) figure is based on the trend for the 1960s (table 2), but the pessimistic (low) figure is based on a less hopeful judgment.

Table 2 shows that, rather surprisingly, agricultural productivity (measured as farm output per unit of inputs) has been increasing at about the same rate during the 1970s as during the 1960s. This is despite a sharp drop in agricultural yields and the widespread belief that agricultural productivity is slowing down because of (*a*) high prices for fertilizer and other energy intensive inputs, (*b*) diminishing returns to nonland inputs in agricultural

Table 1. Projected Urbanization of Rural Lands from 1977 to 2000 Assuming the Continuation of Present Trends

Land Use	Stock in 1977 (1000 of Acres)	Conversion/Year (1000 of Acres)	Percentage of Stock Converted 1977–2000	Reserve in 1977 (1000 of Acres)	Percentage of Reserve Converted 1977–2000
All rural land[a]	1,410,000	2500	4.1	N.A.	N.A.
Farmland (cropland, pasture, and range)	955,000	1200	2.9	N.A.	N.A.
Cropland	413,000	730	4.1	135,000	12.4
Prime agricultural land (SCS classes I & II)	326,000	910	6.4	47,000	44.5

Sources: Dideriksen, Hidlebaugh and Schmude (1977) and USDA Soil Conservation Service (1979).
[a] Excludes federally owned land and Alaska.

may overestimate the loss of rural land to urbanization because of a classification problem. In 1967, urban areas of less than 10 acres were classified as "other land" by the SCS. Other land accounted for 4% of the nonfederal rural land in 1967; but, according to the PCS, 25% of the land converted to urban uses during 1967–75 was formerly "other land." Thus, the rapid growth of small rural areas in recent years may have resulted in a reclassification of many of these areas from "other land" to urban and built-up uses (Lee, p. 16). See also Vining, Plaut, and Bieri for a further discussion of the PCS estimates.

Putting the Estimates into Perspective

Are these estimates of the national loss of farmland to urbanization large or small? Some perspective on the magnitude of these figures can be obtained by relating them to the stock and the "reserve" of agricultural land in the country (the latter concept will be defined shortly).

From table 1, it can be seen that in relation to its stock, the loss of agricultural land to urbanization does not appear to be overly alarming. By assuming that the present losses will continue into the future, it is calculated that no more than 3% to 7% of the land in any of the four rural land uses will be converted to urban uses by the year 2000.

However, these comparisons may be misleading. Rather than view the loss of agricultural land in relation to its stock, perhaps we should relate it to the reserve—that is, to the amount of agricultural land that is currently not being farmed but could be brought into agricultural production, if needed, at relatively low cost. (Note that the term "reserve" does not refer to a conscious government effort to keep land out of production.) In other words, one could ask: For every acre of farmland lost to urbanization, is there another acre of equally productive nonfarmed land that could easily be brought into agricultural production?

The 1977 *National Resource Inventories* have identified about 135 million acres of land not currently being cropped and with a high or medium potential for conversion to cropland (under 1976 commodity prices, development costs, and production costs). Of this total, about 47 million acres is prime agricultural land. This land is assumed to constitute the country's reserve of potential cropland. According to the 1975 PCS, 74% of our potential cropland is currently used for pasture and range.

From table 1, it can be seen that, in relation to the reserve, the loss of farmland to urbanization appears to be more disturbing. With present trends, the amount of cropland urbanized by the year 2000 will be equal to over 10% of the cropland currently available in reserve, and the urbanization of prime agricultural land will equal almost one-half of the current reserve.

Future Farmland Needs

Current estimates of the loss of farmland to urbanization suggest that the continued loss of farmland to urbanization could have a constraining effect on future increases in agricultural output if it is necessary to bring more agricultural land into production. Thus, it is important to estimate how much additional land will be needed in order to support agricultural output in the future and see if these land needs will exceed the amount of land that will be readily available for agricultural use.

Here, future farmland needs are estimated by using the National-Interregional Agricultural Projections (NIAP) system developed by the Economic Research Service (now the Economics, Statistics, and Cooperatives Service) of the U.S. Department of Agriculture (Yeh; and Yeh, Tweeten, Quance). Yeh, Tweeten, and Quance, in particular, have developed several output and price projections from the NIAP system and have argued that "long-run U.S. farm production capacity is

Urban Expansion and the Loss of Farmland in the United States: Implications for the Future

Thomas R. Plaut

As our cities and towns grow and decentralize, farmland and other rural lands are converted to urban uses. The loss of agricultural land to urbanization in this country has evoked little concern in the past. Because of the recent period of food price inflation and agricultural shortages across the world, however, some observers have begun to worry that the continued loss of farmland to urban uses may interfere with the United States' long-run ability to produce food and fiber for itself and for the rest of the world. (See Brubaker, Crosson 1977, Pimentel et al. 1975, 1976, Schiff. For alternative views, see Heady and Timmons, Gardner, and the U.S. Department of Agriculture 1974.) This concern becomes even more serious if one expects that, in the future, energy and other nonland inputs to agricultural production may become very expensive (and/or be in short supply) and the country may be forced to return to a more land-based form of agriculture. Because of the high costs associated with "reconverting" land back from urban to agricultural uses, it is important to consider if the continued loss of farmland to urbanization could exacerbate a possible shortage of productive agricultural land in the future.

The above concerns point out the need to relate systematically the urbanization of farmland to future farmland needs and to analyze whether or not a future conflict is probable. In this paper, we begin to explore this question.

It should be noted that this paper considers only the most direct effect of urbanization on agricultural production—the conversion of agricultural land to urban uses. However, the negative externalities caused by nearby urban development can also have important indirect effects on agricultural production. These include: (*a*) the idling of farmland in areas under extreme urban pressures (Berry 1976, Plaut, pp. 176–82) and over a wider geographic area, (*b*) the switchover to less capital-intensive forms of farming (Berry 1978, 1979). Thus, even though agricultural land is not converted to urban uses, potential agricultural production is lost. The reason for not including this loss in our analysis is that, presumably, under high demand pressures much of this idled and less intensively farmed land could be brought back into intense farm production.

The Urbanization of Agricultural Land

Two recent studies by the Soil Conservation Service have provided some up-to-date estimates of the national loss of rural lands to urban and built-up uses.[1] Based on a subsample of the points used in the 1967 *Conservation Needs Inventory*, the 1975 *Potential Cropland Study* (Dideriksen, Hidlebaugh, Schmude) found that the national loss of agricultural land to urbanization is much higher than previous studies have suggested. In particular, the study reports that the annual urbanization of rural land increased from 1.2 million acres during 1958–67 (Hart) to 2.1 million acres during 1967–75. The PCS estimates also indicate that 36% of the land lost to urbanization is prime farmland (soil capability class I and II). This last figure is somewhat surprising since only 23% of U.S. nonurban, nonfederally owned land is in prime soils.

The 1977 *National Resource Inventories* are based on a much larger sample of 200,000 points (41,000 points were used in the PCS). Preliminary results from this study indicate that the average annual loss of rural land to urban and built-up uses during 1967–77 was 2.9 million acres. This figure may be a little high, however, because it is based on the direct comparison of the estimated urban and built-up areas in 1967 and 1977; the 1967 figure might be too low.[2] Estimates of the urbanization of rural land by previous use are not available because the sample points are different from those used in the 1967 CNI. Thus, the estimates of rural land conversion shown in table 1 were obtained by (*a*) using an intermediate estimate of the urbanization of all rural land (2.5 million acres per year) and (*b*) assuming that the proportion of land converted in each use is the same as reported by the PCS.

It should be noted that the recent SCS studies

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[1] Urban uses include residences, commercial establishments, industrial sites, institutions, airports, public recreational areas, roads, highways, and railroad acreages.

[2] Telephone conversation with Raymond Dideriksen, Director of the Inventory and Monitoring Division, Soil Conservation Service, on 26 October 1979. According to Dideriksen, the 1967 estimate of urban and built-up area may have been influenced partially by the Census figure, which includes only urbanized areas of SMSAs.

Table 1. Comparison of Route Development Results Using the Clarke-Wright Method and Districting Analysis for One Week's Delivery to Customers of Wholesale Milk Processor

Route Characteristics	Clarke-Wright	Districting
Number of routes	38	38
Distance traveled (miles)		
Total	1,090.5	1,168.1
Average/route	28.7	30.7
Standard deviation	6.6	7.1
Time required (hours)		
Total	275.4	282.2
Average/route	7.2	7.4
Standard deviation	1.9	1.7
Stops served	1,033	1,033
Average/route	27.2	27.2
Standard deviation	11.8	10.0

proved routing network required 34% fewer travel miles and 29% less travel time than the existing network.

Data presented in table 1 give the results for the Clarke-Wright and the districting analyses. The data indicate that both procedures give similar results. Each requires the same number of routes to serve the firm's 1,033 weekly customers. Total distance traveled and time required are slightly higher for districting, 7.1% and 2.5%, respectively.

Standard deviations are also similar; however, the values for travel time and stops served per route are lower for districting analysis. This would be important to route management in their attempts to balance the work loads of their drivers.

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References

Berlin, Geoffrey N. "Computerized Residential Refuse Districting." *J. Urban Plan.* 100(1974):173–80.

Clarke, G., and J. W. Wright. "Scheduling of Vehicles from a Central Depot to a Number of Delivery Points." *Operations Res.* 12(1964):568–81.

Glover, F., J. Hultz, and D. Klingman. "Improved Computer-Based Planning Techniques, Part 1." *Interfaces* 8(1978):16–25.

Glover, F., J. Hultz, D. Klingman, and J. Stutz. "Generalized Networks: Fundamental Computer-Based Planning Tool." *Manage. Sci.* 24(1978):1209–20.

Hallberg, M. C., and W. R. Kriebel. "A Routing Algorithm Using the Nearest Neighbor Concept." *Amer. J. Agr. Econ.* 61(1979):87–90.

Hallberg, M. C., and W. R. Kriebel. *Designing Efficient Pickup and Delivery Route Systems by Computer.* Pennsylvania State University Agr. Exp. Sta. Bull. 728, June 1972.

Hardy, William E., Jr. *A Computer Program for Locating Economic Facilities.* Alabama State University Agr. Exp. Sta. Agr. Econ. Ser. 24, Mar. 1973.

Hardy, William E., Jr., and Curtis L. Grissom. "An Economic Analysis of a Regionalized Rural Solid Waste Management System." *Amer. J. Agr. Econ.* 58(1976):179–85.

Mulvey, J. M., and Harlan P. Crowder. "Cluster Analysis: An Application of LaGrangian Relaxation." *Manage. Sci.* 25(1979):329–40.

Murphy, Vayden L., Jr., and William E. Hardy, Jr. *Efficient Vehicle Routing: A Milk Distribution Example.* Alabama State University Agr. Exp. Sta. Bull. 511, Feb. 1979.

Russell, R., and W. Igo. "An Assignment Routing Problem." *Networks* 9(1979):1–17.

Schruben, L. W., and R. E. Clifton. "The Lockset Method of Sequential Programming Applied to Routing Delivery and Pickup Trucks." *Amer. J. Agr. Econ.* 50(1968):854–67.

Thoreson, J., and J. Liittschwager. "Legislative Districting by Computer Simulation." *Behavioral Sci.* 12(1967):237–47.

Turner, Wayne C., P. M. Ghare, and Leslie R. Fourds. "Transportation Routing Problem, A Survey." *AIIE Transp.* 6(1974):288–301.

Weaver, J. B., and W. W. Hess. "A Procedure for Nonpartisan Districting: Development of Computer Techniques." *Yale Law J.* 73(1963):299–308.

each service point i, S_j is the maximum capacity of each district j, T_j is the minimum capacity of each district j, and K is the number of districts to be established.

Equations (1) through (6) indicate that the districting procedure could be formulated as a zero-one, mixed-integer programming problem. As indicated earlier, however, most techniques which attempt to find optimal solutions to combinatorial problems, such as those seen in the vehicle routing and scheduling context, take excessive amounts of computer time. Hypothetical problems using the above model were run with the IBM MPSX mixed integer package on an IBM 370/158. A small model with twenty-five stops and two districts took two minutes and fifteen seconds of CPU time. A larger model with fifty stops and fourteen districts did not reach an optimal solution after two hours.[1]

Because of the computational time difficulties, a heuristic procedure was developed to complete the districting analysis. The procedure uses the combined logic of location-allocation models and the conventional transportation model of linear programming in an iterative fashion to divide a given service area into a set of districts. The steps in the technique are as follows:

(*a*) Select an initial set of district centers. The number of centers is dictated by the total demand in the service area and the number of vehicles available. This step is similar to facility location problems in which an objective function based on the weighted spatial distances or costs connecting each service point to each potential center is minimized (Hardy). It may be expressed as follows:

$$\text{(7)} \qquad \text{Minimize} \sum_i \sum_j A_{ij} C_{ij} M_j,$$

subject to

$$\sum_j A_{ij} = D_i \text{ for all } i, \text{ and}$$

$$\text{(9)} \qquad \sum_j M_j = K,$$

where the variables have the same definitions as in equations (1) through (6). The only difference between this model and the zero-one, mixed-integer programming model presented earlier is the absence of the capacity constraints.

(*b*) Assign all service points a center, thereby forming service districts. This is the conventional capacitated transportation problem which may be stated as

$$\text{(10)} \qquad \text{Minimize} \sum_i \sum_k C_{ik} A_{ik},$$

subject to

$$\text{(11)} \qquad \sum_i A_{ik} \leq S_k \text{ for all } k,$$

$$\text{(12)} \qquad \sum_i A_{ik} \geq T_k \text{ for all } k,$$

$$\text{(13)} \qquad \sum_k A_{ik} = D_i \text{ for all } i, \text{ and}$$

$$\text{(14)} \qquad A_{ik} \geq 0 \text{ for all } i \text{ and } k.$$

(*c*) Measure the compactness of the derived districts. Compactness is defined as the maximum distance separating any service point from its district center, the maximum distance between the most extreme points in each district, the weighted total distance from all points to their respective center (the value of the objective function in step *b*), and so forth.

(*d*) Determine a new center for each district using the technique described in step (*a*) with the value of K equal to 1. These centers may or may not be the same as those used to develop the districts initially.

(*e*) Using these new centers, follow the procedure in (*b*) to reassign service points to the set of capacitated districts. Districts may or may not change from the previous stage.

(*f*) Measure the compactness of these districts. If compactness has improved over the last measure, return to step (*d*). If there is no improvement, then take previous results as best and proceed to step (*g*).

(*g*) Examine the final compact districts and manually determine the path for vehicles to travel in serving all points. The number of stops to be served per district should be small enough so that most feasible routing alternatives could be examined and evaluated manually. In addition, hard-to-quantify variables, such as one-way streets, railroads, busy thoroughfares, and steep grades, could be handled with ease.

Empirical Results

The urban delivery network of a wholesale milk processor was analyzed to permit a comparison of routes developed using the Clarke-Wright method with those generated through districting analysis. Previous research results (Murphy and Hardy) indicated that significant improvements in routing efficiency for this distribution system could be realized from routes developed by the Clarke-Wright method. The analysis revealed that the im-

[1] Recent advances in computational technology and computer software (Glover, Hultz and Klingman; Glover, Hultz, Klingman and Stutz; Mulvey and Crowder) permit certain types of large-scale, mixed-integer programming problems to be solved quickly and efficiently. These techniques, however, are proprietary and as such are not readily available to the general researcher. Also they are somewhat difficult to use because programs, or at least subroutines, must be developed for each individual application. The districting heuristic model presented in this report is based upon the IBM MPSX program package which is found at many computer installations.

Vehicle Routing Efficiency—A Comparison of Districting Analysis and the Clarke-Wright Method

William E. Hardy, Jr.

Continued cost increases associated with the transportation of raw materials and final products are forcing management to examine more closely the economic efficiency of their operations. A basic problem facing the transportation manager is to schedule and direct a fleet of vehicles to a set of stops or destinations, such that only one vehicle visits each stop. The objective is to minimize the total cost of delivery. Normally, travel distance is used as a surrogate measure of cost, or it is assumed that cost is proportional to distance. Most analyses attempt to satisfy this minimization objective while being constrained by such variables as vehicle capacity, maximum route length, maximum route time, and special customer service time constraints.

Both heuristic procedures and models that will give optimal solutions have been used extensively to solve routing problems (Turner, Ghare, Fourds). Most emphasis in the literature and in practical industrial applications has been placed on heuristic techniques, because computational time increases exponentially with problem size. This computational problem is particularly evident in models which seek optimality. In most cases, the additional accuracy obtained by using these models does not justify the added time and expense required.

One of the first and most often referenced heuristic techniques was developed by Clarke and Wright. Their procedure, or modifications and extensions of the technique, has served as the basis for many successful applications (Hallberg and Kriebel 1972, 1979; Hardy and Grissom; Murphy and Hardy; Russell and Igo; Schruben and Clifton).

Routing analyses of the Clarke-Wright type give definite, explicit routes that should be followed in satisfying the demands of the specified service area. The apparent rigidity and inflexibility of these research results has led to some reluctance on the part of route managers to implement the findings of detailed routing analyses. Some feel that their decision-making powers are being replaced or, at best, supplanted by the quantitative analysis. A more valid complaint often expressed is that there are objectives and constraining variables which should be considered in establishing routes that are not quantifiable and thus cannot be included in the analyses.

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Districting for Route Development

An alternative quantitative method which would be of assistance to a route manager in developing efficient route systems without dictating the specific paths the vehicle would follow is the concept of districting. This technique has been used successfully in delineating compact and balanced districts for schools, political boundaries, and planning regions (Thoreson and Liittschwager; Weaver and Hess). It also has been used to a limited extent in developing transportation systems (Berlin).

There is a single basic difference between the results of a Clarke-Wright analysis and those provided by a districting analysis. The Clarke-Wright technique specifies the exact sequence of stops, permitting little room for management discretion. Districting analysis, however, simply groups the demand points of the total service area into a specified number of compact service districts. Actual route design for each of these smaller districts is left to management. The number of stops in each district should be small enough so that most reasonable routing alternatives should be obvious.

Mathematically, the districting problem may be expressed as follows:

$$\text{(1)} \qquad \text{Minimize} \sum_i \sum_j A_{ij} C_{ij} M_j,$$

subject to

$$\text{(2)} \qquad \sum_i A_{ij} \leq S_j \text{ for all } j,$$

$$\text{(3)} \qquad \sum_i A_{ij} \geq T_j \text{ for all } j,$$

$$\text{(4)} \qquad \sum_j A_{ij} = D_i \text{ for all } i,$$

$$\text{(5)} \qquad \sum_j M_j = K, \text{ and}$$

$$\text{(6)} \qquad A_{ij}, M_j \geq O,$$

where A_{ij} indicates whether the demand from service point i is served in district j, C_{ij} is the cost or distance between service point i and district center j, M_j is a zero-one variable indicating whether point j is a district center, D_i is the service requirement of

Table 2. Determinants of Relative Breeding Effects

	Profit-ability (*P*)	Growth Rate (*G*)	Vari-ability (*V*)
Coefficients in 1974 (table 1)	4.07	56.24	5616
Orange crop parameters	171.5	1.0	0.26
Percentage of income change from percent change in parameter	2.32	28.77	1.11

creases in average grower income. In particular the regression coefficients suggest that a 1% increase in crop profitability (for example through a small increase in labor productivity) would yield an increase in grower income of about 2%. A 1% increase in the logistic constant of growth (for example an orange tree that matured about a month earlier) would yield an income increase of around 29%. A 1% decrease in crop variance (for example through a crop resistant to perhaps 5% of local diseases on Atiu) would yield an income increase of about 1%.

Of course nothing can be said about the relative merits of different breeding strategies without knowing how difficult it is to obtain each of these improvements. To investigate this it might be possible to use an approach like that of Liyanage. He estimated the expected genetic progress of a series of traits in the progeny of an adult plant. His work with coconuts, for example, suggested that despite improvements already attained, it was still easier to achieve a given percentage change in crop yield than in fruit-maturing time.

Despite this observation and our ignorance of the breeding performance of orange trees, it seems safe to conclude that a suboptimal approach was taken in the breeding of improved orange trees for Atiu: the ideal tree should have been above all fast growing. It is more difficult to confidently rank variability, profitability and other design characteristics.

This leaves an important question unanswered: most of the interest in new varieties is centered not on tree crops but on cereals, where speed to maturity is less crucial than variability and yields. The general evidence here is that high yields may have been overrated at the expense of low risk. To test this more precisely requires knowledge of the different components of these two aggregated design traits. For example, Pinstrup-Andersen, de Londoño, and Infante suggest a method to estimate the extent of different causes of yield variance in crops. With knowledge of these disaggregated subparameters, it is possible to conduct simple genetic experiments to investigate directly the tradeoffs involved, and the optimal design strategies.

Another question of practical relevance is whether it is necessary to have detailed records of past grower participation as in the special case of Atiu in order to estimate likely future responses. A recent study by Dillon and Scandizzo suggests that it may after all be possible to gather sufficient meaningful information (about risk preferences for example), by careful survey work before a project is designed.

In making policy recommendations from this analysis, the limiting statistical assumptions made, the quality of the data used, and the ignorance about relative breeding costs, all must be remembered. But although it may not be possible to obtain estimates of absolute gains from breeding, the formulation does highlight a number of things: just what "improved" crop varieties are likely to involve; how dependent choice of ideal crop technique is on the particular attitudes of a grower community (and, hence, how site-specific crop design may have to be); and the significance of the relative costing decisions that are all the time being made implicitly by crop breeders.

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References

Bollard, A. E. *Agricultural Project Design and Evaluation in an Island Community*. D.S.C. Monograph No. 15, Australian National University, Canberra, 1979a.

———. "The Design and Administration of New Crops: Grower Response to Change." *J. Econ. Develop.* 4(1979b):171–88.

Dillon, J. L., and P. L. Scandizzo. "Risk Attitudes of Subsistence Farmers in Northeast Brazil: A Sampling Approach." *Amer. J. Agr. Econ.* 60(1978):425–35.

Flynn, J. C. "Focussing Farm Systems Research on Smallholder Agriculture." *The Adaptation of Traditional Systems of Agriculture*, ed. E. K. Fisk, pp. 257–76. Canberra: Australian National University, 1978.

Ladd, G. W., and C. Gibson. "Microeconomics of Technical Change: What's a Better Animal Worth?" *Amer. J. Agr. Econ.* 60(1978):236–40.

Liyanage, D. V. "Genetic Improvement of the Coconut Palm." *Communications of the Tenth Pacific Science Congress*, pp. 39–50. Symposium on Tropical Crops Improvement, Hawaii, 1961.

Perrin, R., and D. Winkelmann. "Impediments to Technical Progress on Small versus Large Farms." *Amer. J. Agr. Econ.* 58(1976):888–94.

Pinstrup-Andersen, P., N. de Londoño, and M. Infante. "A Suggested Procedure for Estimating Yield and Production Losses in Crops." *PANS* 22(1976):359–65.

Sanders, J. H., and J. Lynam. "Systems of Production of Beans and Cassava in Latin America with Implications for Research Design." Paper delivered at the Conference on the Adaptation of Traditional Systems of Agriculture, Solomon Islands, 1977, sponsored by Development Studies Centre, Australian National University, Canberra.

dently of managed inputs. Again, there are a number of subparameters of interest: the changing pattern of returns over time, the time taken to maturity, etc. The potential (not necessarily achieved and not observable) rate of growth of yield (G) is here measured by the logistic constant of the S-shaped potential growth curve. Tree crops that take a long time to mature have a low G value, while fast maturing crops have a higher value.

The third crop characteristic examined is the risk involved. This includes biological variations in yield, variations in the proportion of the crop reaching market in salable condition, and variation in market price. This crop variability (V) is approximated by the variance of revenue actually received by growers, adjusted about a production trend to take account of varying inputs. Perishable crops like tomatoes have higher V-values than less sensitive ones like forest trees.

Values for the explanatory variables P and V came from field data collected in 1974–75 on Atiu. They cover ten project crops available to growers in the previous decade. Estimates for G were derived from experimental data on the potential performance of similar crops under controlled conditions.[2] The dependent variable, grower participation, is represented by the annual household income (Y) received from each crop. These data were derived from the detailed planting and marketing records maintained on the island, and were available for all of the 200 households for the period under study.[3]

It is now possible to test the hypothesis that grower participation in a crop depends, among other things, on the structural crop design—specifically its profitability—growth rate, and variability as measured above. For estimation, a roughly linear explanatory relationship is assumed:

$$Y = \beta_0 + \beta_1 P + \beta_2 G + \beta_3 V. \tag{1}$$

It already has been claimed from observation that Atiuans like quick returns but dislike risk; that is,

$$\beta_1, \beta_2 > 0; \beta_3 < 0.$$

But what is more at issue is how important a typical grower considers each of these crop design traits to be relative to the other ones.

The coefficients of equation (1) were estimated for the range of crops available to growers over the period 1965 to 1974. The data were grouped into four subperiods in order to allow sufficient observations during the earlier years when there were fewer crop possibilities available. These subperiods are not long enough to allow structural distortions to take place. (Figures for 1968 are omitted because a hurricane early that year severely disrupted production.)

The regression results are presented in table 1. They offer a consistent picture: as predicted, growers seem to appreciate profitable crops, they like fast maturing ones (with one nonsignificant exception), and they try to avoid risky ones. The statistical fits are reasonable, although given the quality of the data and the number of observations, too much confidence should not be placed on this.

Optimal Crop Design

The most interesting part of these results for us is the relative magnitude of each coefficient, for this is an indication of the importance of each production trait in determining participation. However, these coefficients are measured in different units and are not directly comparable. Furthermore, just how difficult it will be for breeders to affect equivalent changes in each of these production parameters is not known (although, of course, every time breeders aim for a particular trait, they are making an implicit analysis of the relative opportunity costs of neglecting other heritable traits).

Take the case of an orange breeder seeking to develop an improved strain of trees for his community. What should he or she breed for? Assuming coefficients roughly of the order of magnitude of those estimated in the regression for 1974, it can be shown what the approximate range of relative breeding costs should be for a breeder to give priority to improvements in either profitability or growth rate or variance. This assumes that changes in any of these traits can be achieved independently of the others, and that improvements in a trait have the same probability of being passed on between generations.

It can now be seen (table 2) that if a breeder were to achieve a fixed percentage improvement in each trait in turn, he would elicit different relative in-

Table 1. $Y = \beta_0 + \beta_1 P + \beta_2 G + \beta_3 V$

	β_0	β_1	β_2	β_3	R^2
$Y_{1965-69}$	3384	17.84***[a]	−29.60	−8790*	.65
(n = 24)		(4.81)	(0.66)	(1.51)	
$Y_{1970-71}$	1538	4.91**	11.71***	−3875	.75
(n = 16)		(2.48)	(2.92)	(2.31)	
$Y_{1972-73}$	1328	10.61***	34.51***	−4284**	.87
(n = 18)		(3.12)	(6.36)	(1.94)	
Y_{1974}	1317	4.07	56.24***	−5616*	.95
(n = 10)		(0.52)	(7.66)	(1.81)	

[a] *, **, *** indicate significance > 0 at 90%, 95%, 99% levels of confidence, respectively.

[2] There clearly are other things that determine grower interest in crops apart from points of technical design. Examples are the stock of knowledge possessed by a grower about a crop, the attitude of fellow growers toward it, and the role of the administration in cushioning its introduction. In this study, as in Perrin and Winkelmann's, these were all found to play an important role in acceptance.

[3] It was also possible to test an alternative measure of grower participation, namely the average household labor devoted to a crop, for one year only. The source of this data was an extensive labor use survey carried out by the author. Regression results were similar.

tractors and implements, and an assurance of potentially high yields.

How did Atiuan growers respond? Exhorted by government and some local leaders, most were keen to join (164 plots were planted in six years), and they worked hard at clearing, planting, watering, and weeding. But after a few seasons, growers began to tire of waiting for the oranges to mature. They found the maintenance especially irksome because it had to be done regularly and privately, clashing with traditional work patterns. And having grown their old oranges satisfactorily without fertilizing, spraying, or pruning, they were not convinced that these practices were worthwhile, and neglected them.

The trees proved botanically ill-suited to the Atiuan environment: sea winds and salt air in exposed places damaged delicate foliage. Some plots suffered from soil deficiencies, while droughts stunted growth and hurricanes broke boughs. Yields were marked by extremes of biennial bearing (alternate good and bad years). Oranges suffered from white moth infestations, sooty mold, and scaly bark diseases, against which they had no natural resistance.

Support services were quite inadequate. A locally trained agricultural officer could offer only limited technical advice. Machinery, fertilizer, and sprays were available irregularly, and often unavailable when most needed. Shipping, too, was unpredictable and usually inadequate.

As a result, by the time the trees should have reached maturity they were stunted and diseased. Yields over the next twenty years averaged only 40% of expected output; with low produce prices and heavy emigration from the island about 80% of plots fell heavily into debt, their owners having lost interest in them.

This decline was hastened by the administration introducing a whole series of other short- and long-term cash crops over the next twenty years. These included forest trees, tomatoes, peanuts, coffee, pineapples, and other vegetables. For the most part these were also "improved" varieties of crops that had been grown previously or harvested from the wild. A variety of technical and marketing innovations accompanied them (see Bollard 1979a).

Unfortunately, not much had been learned from the Citrus Replanting Scheme. Most of these new crops were also poorly suited and did not perform well. Atiuan growers were characteristically choosy about which ones they wanted to grow. For all its ineptitude in crop introduction, the local administration did keep detailed records of individual grower participation in each crop. These records now are used to draw conclusions about what sort of crops would have been most desirable (as indicated by grower response) in the first place.

It appears that the profitability of a new crop was an important consideration for Atiuan growers; though in common with most Polynesians, extra income did not act as a strong inducement after certain household needs had been provided for. On the other hand extra work, especially regular monotonous jobs that threatened to cut into important social activities, could be distasteful. Like most low income farmers, Atiuans displayed positive risk premiums and sought insurance against uncertainty. Further, they gave evidence of low rates of time preference by selecting faster maturing crops. Growers also seemed to avoid crops they knew little about and were attracted by the presence of other growers in a bandwagon effect.

This is all important information for the crop breeder. Yet it is much too general to help him decide between different research paths. In fact it does not distinguish the Atiuan farmer from most other third world growers. So it is necessary to test the importance of each of these technical crop characteristics in a more precise way. This is done by estimating to what extent each of a number of crop parameters can explain the pattern of grower participation.

The production possibilities of the crops are now specified so as to highlight in a simplified way those technical points of design that growers look at and respond to. This is done by developing a nonstationary production function that specifies profitability, variability, and rate of growth as a series of estimable parameters. Each of these parameters is, of course, a highly aggregated measure subsuming many other minor technical characteristics. This production function is more fully described elsewhere (Bollard 1979b).

The function is designed to explain the performance of slow growing crops (reducing in the short term to include annual crops as a limiting case), where the only significant input is household labor in its various roles. On Atiu, crops are grown by extended household groups with unpaid family labor constituting the only significant costs. The specification is based on the principle that the current and future performance of a crop depends on its current inputs, its natural age, and how well it has been looked after in the past.

The first crop characteristic considered is its profitability. Included in this are many of the farmer's early questions, such as: What will the harvest yield be? How much money will that be worth? And, how much work will it require? For the steady state, a common exponential relationship of returns and labor is assumed.[1] Then profitability (P) is measured by the marginal revenue product of labor in the steady state adjusted for the current level of production. For fast maturing annual crops, this reduces to the simple marginal revenue product. For other agricultural systems the presence of other factor costs may require more involved measures.

A second characteristic of tree crops is that as they grow older, production will increase indepen-

[1] The specific form used is the Mitscherlich function, because it provides useful subparameters, like the fixed labor required to commence production and the asymptotic maximum potential yield.

Grower Preference for Crops and Implications for Plant Breeders

Alan E. Bollard

In an article in this *Journal*, Perrin and Winkelmann summarize the patterns of adoption of new wheat and maize varieties in developing countries. Their general conclusion is that agricultural technology is more site-specific than has been believed. Their warning to the plant breeder is that, in areas not already dominated by new varieties, it is unlikely that any single new variety could repeat the early successes.

This leaves scientists in crop research institutions in something of a quandary. The era of massive improvements in yields is past. In any case, they are well aware that crops bred purely for their high yields are not completely satisfactory and may even be dangerous for their vulnerable low income small farmer clients. (See, for example, Flynn.)

It is clear that efficient plant design requires a knowledge of the prevailing natural growing environment and available technical infrastructure, as well as an appreciation of the social and cultural character of the people involved. But it is not always clear precisely which plant characteristics scientists should be breeding for, nor how they should weight relative breeding priorities when there is a trade-off, other than by what Sanders and Lynam call the subjective method of "critical inference."

One approach is that followed by Ladd and Gibson in a recent article. They investigate breeding priorities for hog improvement in the United States. By estimating potential increases in profit to be had, they can recommend between breeding for each of three heritable traits. However, their objectives are much more limited: these traits are all yield-increasing ones, and so their deterministic approach ignores all the complications of predicting the behavior of growers faced with risk, choice over time, and other culture-bound decisions.

This note takes the site-specific approach recommended by Perrin and Winkelmann. It describes a study made of a small homogenous community in the Pacific, and reactions there to the introduction of a variety of new cash crops including tree crops. Although both people and crops are quite different to the cases of Perrin and Winkelmann, several of the findings about patterns of crop adoption are similar. Appropriate research priorities for breeders are then investigated.

The format is as follows: section two uses the experiences of growers with new crops to estimate the extent to which different technical crops have affected decisions to participate in projects in the past. The third section investigates how far this information may be used to indicate those crop traits that could be expected to draw the most enthusiastic response from these particular growers. It is not clear, even in this small homogenous community, just what the optimal crop design is; but it can be shown that current designs are suboptimal, and that they may be improved.

New Crops for Atiu

Atiu is a small coral atoll in the Cook Islands in the South Pacific. The population of 1,380 lives in adjoining villages and are mixed subsistence farmers and cash croppers. Until the mid-twentieth century Atiuans earned small amounts of cash, mainly by picking the fruit of the native orange trees. These straggling self-sown trees bore regular yields of poor quality fruit without any cultivation. Picking was done by the small boys who climbed the trees and threw down the tough oranges. This system corresponded well to the communal work habits and the traditions of food gathering rather than modern agricultural cultivation.

In the 1940s the orange trees became exposed to new diseases and began to die out. The New Zealand government decided that improved orange varieties should be introduced through an aid project. The question was what the best type of tree would be. The criteria decided on were typical of agricultural projects of the time. The trees must be high-yielding, with top grade fruit. To minimize labor, low varieties were to be planted symmetrically in large, mechanizable, cleared plots, each to be privately managed by an individual nuclear family. They were to make full use of new Western citricultural techniques such as heavy fertilizing, pruning for light, and machine spraying against pests and diseases.

In 1951, two new varieties of "improved" trees on lemon rootstocks were offered to Atiuan growers with suitable lands. With the seedlings came advice on cultivation, credit (to be repaid out of later proceeds) to purchase materials, use of

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Helmberger, J. D. "The Market for Agricultural Economists." *Amer. J. Agr. Econ.* 55(1973):725–34.

Kearl, C. D. "Report of the Secretary-Treasurer." *Amer. J. Agr. Econ.* 50(1968):1769–74.

Melichar, Emanuel. "Characteristics and Salaries of Agricultural Economists." *Amer. J. Agr. Econ.* 51 (1969):903–11.

Redman, J. C., ed. *Amer. J. Agr. Econ. Handbook Directory* 54(1972), no. 4, part 2.

Redman, J. C., ed. *Amer. J. Agr. Econ. Handbook-Directory* 58(1976), no. 4, part 2.

U.S. Department of Agriculture, CSRS. *Professional Workers in State Agricultural Experiment Stations and Other Cooperating Institutions.* Agr. Handbook No. 305, Dec. 1965, rev. Jan. 1976.

U.S. Department of Health, Education, and Welfare; Public Health Service; Health Resources Administration; National Center for Health Statistics (HEW). Washington, D.C.: *Vital Statistics of the U.S. 1973.*, vol. 2, sec. 5, 1975.

U.S. Office of Education. *Earned Degrees Conferred.* Washington, D.C., various issues.

Table 6. Age by Major Area of Specialization, 1975

Major Area	Age 61–65	56–60	51–55	46–50	41–45	36–40	31–35	26–30	Total
Production farm mgmt.	16	45	74	89	85	83	83	31	506
Finance	4	18	9	9	17	15	14	3	89
Marketing	39	52	90	68	88	65	87	27	516
Policy	27	25	31	35	32	26	20	8	204
Supply, demand, outlook	7	5	16	10	25	29	27	9	128
Natural & comm. res.	35	23	66	59	104	102	114	43	546
Human resources & consumer econ.	4	4	11	10	26	18	16	4	93
Economic theory	7	15	15	16	17	19	17	7	113
Economic development	12	15	25	30	44	48	42	6	222
Statistical methods & econometrics	5	0	11	5	19	21	32	10	103
International agr. trade	3	1	9	7	1	0	7	1	29
Other	7	18	24	22	31	35	35	12	184

Note: Based on the distribution of reporting members in the 1976 *AJAE Handbook-Directory* and adjusted for nonreporting by the ratio of the estimated number of individuals in age group *i* in 1975, to the number of reporting members in age group *i* in 1976 *Handbook-Directory*.

government or private industry each year. This leaves 61 new Ph.D.s to cover annual replacement needs of universities. Deducting the 50 per year required to cover retirements and death leaves 11 new Ph.D.s per year to cover resignations (shifts to administrative positions as well as changes of profession), positions created through upgraded educational requirements, and entirely new positions. The projected replacement needs for the early 1980s will absorb all of the new Ph.D.s destined for university employment under the Fuller scenario.

Table 5 contains the estimated age distribution in 1975 by employer.[4] Academic institutions continue to be the major employer and will have the greatest replacement needs. The overall distribution by type of employer is similar to Fuller's results. Sixty-four percent of the total are employed by colleges and universities.

The areas of specialization of most interest will continue to be production/farm management and marketing (table 6). These areas of specialization will be consistently high in demand. Natural and community resources will have higher replacement needs in the later 1980s. Other areas such as policy and economic development will experience increasing replacement needs but not to the extent of production and marketing.

Several factors have the potential for increasing the supply of Ph.D.s in the United States or reducing the replacement needs in the near future. More intense recruiting of graduate students would increase supply. Increased employment opportunities as well as budgetary restraints may induce more U.S. Ph.D.s, currently employed abroad, to return to the United States. A third factor is the recent change in mandatory retirement laws. Postponing retirement beyond age 65 may be sufficient to alleviate any shortfall. If all retirements occurred at age 70, replacement needs for the period 1981–85 would be 44% of the requirements with retirement at age 65. For the period 1986–90, replacement needs would be 75% of the estimated figure if retirement is delayed five years.

The actual replacement needs likely will be somewhat less than projected with retirement at age 65 and more than implied with retirement at age 70.

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[4] Tables 5 and 6 are generally consistent with the projected age distribution, except for rounding discrepancies. An anomaly occurred in the youngest age group. Ph.D. candidates projecting 1976 completion dates resulted in a larger than forecast number of individuals in this age group.

References

American Farm Economics Association. *The Handbook of the American Farm Economics Association, J. Farm Econ.* 48(1966), no. 4, part 2.

Fuller, Varden. "Employment of Agricultural Economists." *Amer. J. Agr. Econ.* 53(1971):532–4.

Table 4. Estimated Ph.D. Age Distribution, 1975, with Projected Declines

	Age								
Year	61–65	56–60	51–55	46–50	41–45	36–40	31–35	26–30	Total
1975	163	221	383	358	490	461	495	131	2,702
1980	198	358	344	478	454	490	130		2,452
1985	318	322	458	443	483	129			2,153
1990	289	428	425	471	127				1,740

Each age group in each year's age distribution, A_{ij}, was multiplied by the ratio of the sum of U.S. recipients plus one-fourth of the foreign recipients to reporting recipients in the appropriate *Handbook-Directory*. The age distribution of reporting recipients was assumed to be representative of the distribution for all recipients entering the U.S. market.

A review of data on foreign recipients of Ph.D.s in four different years indicated that 44% maintained membership in the AAEA in 1975. Of the 44%, approximately one-half (22% of the total) remained in the United States. It was assumed that 25% of the foreign recipients entered the U.S. labor market. Life expectancy adjustments for these distributions were from 1971 to 1975. Data for degree recipients in the years 1972 thorugh 1975 were obtained from the 1976 handbook. Bibliographic data in the 1976 handbook were obtained in 1975. No life expectancy adjustments were made in the age distributions for these latter years.

Combining the adjusted age distribution from the 1966 handbook and the adjusted age distributions for degree recipients in the years 1967 through 1975 yields the overall age distribution from which the effects of retirement and death are projected. Using a retirement age of 65 and the life expectancy tables, the overall age distribution is projected to the years 1985 and 1990.

The distribution of major specialty by age of reporting Ph.D.s in the 1976 *Handbook-Directory* was combined with the age distribution estimated here to project needs by major specialty. It was assumed that the distribution of reporting members in each age group across major specialties is representative of the population. Within each age group reporting in 1976, the number of individuals indicating a major specialty was adjusted by the ratio of the estimated age group in 1975 to the reporting age group in the 1976 *Handbook-Directory*. The distribution of Ph.D.s by employer according to age was obtained in an analogous manner.

Results and Implications

Table 4 contains the estimated age distribution for all Ph.D. agricultural economists in the United States in 1975. The distributions for 1980, 1985, and 1990 show the anticipated effects of retirement and deaths prior to retirement. It is estimated that 50 new Ph.D.s are needed per year during 1976–80 for replacement. Replacement needs in the first half of the 1980s will average 60 new Ph.D.s and in the second half will average 83 new Ph.D.s per year. The declining number of degrees granted and the increasing proportion of foreign recipients has resulted in a much smaller number of Ph.D.s entering the U.S. market each year. Assuming 25% of the foreign recipients remain in the United States, the average number of new Ph.D.s entering the U.S. market during 1975–77 was 96. Fuller's 1970 survey (excluding foreign positions) has implications for the current market and future trends. Of the 160 recipients entering the 1970 labor market, 64% found employment at universities or colleges (including Extension) and 28% were employed by the federal government. The remaining 8% were employed by private industry and foundations or institutes. If these figures are representative of the current market, 35 new Ph.D.s are being employed by

Table 5. Age by Type of Employer, 1975

Type of Employer	Age								
	61–65	56–60	51–55	46–50	41–45	36–40	31–35	26–30	Total
Academia	101	150	255	237	316	280	299	115	1,753
Government	37	30	81	76	111	101	104	28	568
Private industry	3	12	25	9	19	27	48	4	147
Other	23	30	23	36	45	54	44	14	269
Total	164	222	384	358	491	462	495	161	2,737

Note: Based on the distribution of reporting members in the 1976 *AJAE Handbook-Directory* and adjusted for nonreporting by the ratio of the estimated number of individuals in age group *i* in 1975, to the number of reporting members in age group *i* in 1976 *AJAE Handbook-Directory*.

Table 1. Number of Agricultural Economists at Agricultural Experiment Stations and Other Cooperating State Institutions

	1965	1975
Ph.D.	793	1,249
Master	569	428
Bachelor	138	80
Total	1,500	1,757

Comparison of the number of degrees granted over time with the number of Ph.D.s listed in the three most recent *AJAE Handbook-Directories* indicated the 1966 handbook likely included a higher percentage of Ph.D.s in the United States. Regular membership in the AAEA during the period 1959–66 increased by almost 50% (Kearl). This growth was substantially more than the total number of Ph.D.s granted during the same period and listed in the 1966 handbook—1,098 new regular members versus 593 new Ph.D.s. The total number of Ph.D.s listed in the 1966 handbook is also greater than the total number of degrees granted during the years 1951 through 1966. In addition, the growth in reporting membership by Ph.D.s is substantially less than degrees granted during the years 1967 through 1975. There were 1,515 degrees conferred during this time period (see table 2). The number of reporting Ph.D.s increased by 540 between 1966 and 1975 (see table 3).

Nonreporting Ph.D.s cause a downward bias in the 1966 distribution.[2] The magnitude of this bias was reduced by adjusting the distribution upward. The adjustment factor, N_o, was determined by the ratio of all U.S. degree recipients for the years 1951–66, inclusive, to U.S. degree holders listed in the 1966 handbook. U.S. degree recipients are defined as those individuals whose first degree was awarded by an institution in the U.S. The list of U.S. degree recipients was obtained from the May issues of the *Journal* for the years 1951–66, inclusive.

The estimated distribution for 1966, adjusted for nonreporting, was brought forward to 1975 using a life expectancy adjustment factor, L_{1966j}. This factor explicitly accounts for preretirement deaths.

The yearly listing of Ph.D. recipients in *AJAE* provided the data base for the period 1967 through 1975.[3] Year of birth data were obtained for each class of recipients. The resulting yearly age distributions, A_i, were adjusted to allow for nonreporters and foreign recipients entering the U.S. labor market.

Table 2. Ph.D. Degrees Granted 1951–77, by Citizenship

Year	Total	U.S.	Foreign
1951	57	NA	NA
1952	91	NA	NA
1953	43	NA	NA
1954	93	NA	NA
1955	70	57	13
1956	76	61	15
1957	67	47	20
1958	65	53	12
1959	86	69	17
1960	95	80	15
1961	111	81	30
1962	117	96	21
1963	108	88	20
1964	118	83	35
1965	84	51	33
1966	108	71	37
1967	124	79	45
1968	126	81	45
1969	151	105	46
1970	170	115	55
1971	217	145	72
1972	196	116	80
1973	205	118	87
1974	179	102	77
1975	147	78	69
1976	134	79	55
1977	150	84	66

Source: based on lists of degree recipients published in May issues of *AJAE*.
Note: Citizenship determined by location of institution granting first degree.

Table 3. Age Distribution of Reporting Ph.D.s by *AJAE Handbook-Directory*

Year of Birth	Handbook		
	1966	1971	1976
<1910	171	92	64
1910–14	138	109	78
1915–19	177	134	124
1920–24	274	215	208
1925–29	233	209	205
1930–34	265	298	315
1935–39	135	284	354
1940–44	9	216	462
1945–49		7	164
Not given	38	61	6
Total	1,440	1,625	1,980

Source: *AJAE Handbook-Directory* 1966, 1972, and 1976.

[2] Because interest here is in the U.S. market, two additional sources of bias exist: (*a*) foreign degrees employed outside U.S.; and (*b*) U.S. degrees employed outside U.S. A systematic sample was taken of the 1966 handbook resulting in 144 observations (10%). The first bias represented 1.2% of the sample, and the second bias was 8.3%.

[3] Comparison of the total number of degree recipients published in the May issue of this *Journal* for the years 1959–74, inclusive, with the *Earned Degrees* series (U.S. Office of Education) for the academic years 1959–60 through 1974–75 indicates that underreporting in the May issues is not serious. The *Earned Degrees* series indicates 2,324 Ph.D. degrees granted. The total number of recipients listed for the calendar years 1959–74 in the *AJAE* was 2,212, and for the calendar years 1960–75, the number of degree recipients listed was 2,273.

Projected Replacement Needs for Agricultural Economists

Ralph T. Schotzko

Demand for Ph.D. agricultural economists, in general, comes from academia, government, and private industry. Within each market, employment opportunities result from attrition and newly created positions. New positions may result either from the decision to increase the number of professionals or through upgrading educational requirements of positions vacated through attrition. Attrition includes resignations, retirement, and premature death. This paper presents a projection of replacement needs in the profession as a result of retirement and premature death. No attempt is made to document resignations resulting from administrative appointments or changes in profession.

The potential for new positions in academic institutions, and possibly government, is declining and may be negative. Forecasts of declining college enrollments (Helmberger) portend an academic market that may be reduced to replacement hiring only. Budgetary constraints also may inhibit both funding of new positions and filling of vacant positions.

The potential for upgrading any sizable number of positions is much less now than ten or fifteen years ago. A count of agricultural economists in *Professional Workers in State Agricultural Experiment Stations and Other Cooperating State Institutions* for 1965 and 1975 is provided in table 1.[1] Over that ten-year period, the number of individuals in departments of agricultural economics increased 17% and the number of Ph.D.s increased 58%.

A significant number of agricultural economists are employed at non-land-grant institutions. Employment opportunities at these institutions may be more severely constrained by budgetary and enrollment problems than land-grant universities.

Some growth in the total number of academic positions held by Ph.D.s may occur through movement into administrative positions. Potential mobility of agricultural economists in this direction has not been documented.

Documentation of employment of Ph.D. agricultural economists in the private sector is limited. Of the Ph.D.s listed in the 1976 *American Journal of Agricultural Economics Handbook-Directory* (Redman), 16% were not employed by either academic institutions or government. Melichar's analysis of data in the 1966 *National Register of Scientific and Technical Personnel* indicated this group represented 14% of all agricultural economists. Fuller's 1970 survey also shows a slight shift in beginning employment toward private industry.

While the private sector may be hiring an increasing percentage of agricultural economists, academic institutions continue to be the major employer. The primary reason for employment opportunities at academic institutions likely will be attrition.

Procedures

Using age 65 as the retirement age and life expectancy tables to account for early deaths, two of the three leakages associated with attrition can be estimated. An age distribution for Ph.D. degree holders in 1975 is estimated. This distribution is then used to estimate replacement needs. Data for the distribution were based on the three most recent AAEA handbook-directories and May issues of the *AJAE* for the period 1951–76.

The estimated number of people in the jth age group in 1975, Y_j, was obtained according to the following expression.

$$Y_j \equiv N_0 L_{1966j} X_j + \sum_{i=1967}^{1971} N_i L_{ij} A_{ij} + \sum_{i=1972}^{1975} N_i A_{ij},$$

where N_0 is nonreporting adjustment factor for degree recipients prior to 1967 ($N_0 = 1.37$); L_{ij}, life expectancy adjustment factor from year i to 1975 for the jth age group (HEW); X_j, number of Ph.D. degree holders in the jth age group as listed in the 1966 *Handbook of the American Farm Economics Association;* A_{ij}, number of reporting degree recipients in year i in the jth age group as listed in the appropriate *AJAE Handbook-Directory;* N_i, non-reporting adjustment factor determined by $\dfrac{US_i + 0.25\,F_i}{A_i}$; US_i, U.S. recipients in year i; F_i, foreign recipients of U.S. degrees in year i; and A_i, number of reporting degree recipients in year i.

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These data were collected while the author was an assistant professor of agricultural economics at Rutgers University.

[1] Individuals listed in these directories include college staff, station staff, extension staff, and the staffs of cooperating government agencies.

allegiances, has seen a substantial dropout rate. The FB and FU, with their selective incentives, have seen opposite trends. Yet it is apparent that the views of both writers must be qualified to include the magnitude of farm operation, and, at least for Wisconsin, the role of history as suggested by regional variations.

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References

Cell, Charles P. "Farmer Movements in the Middle West: Sources and Successes." Mimeographed. Madison: University of Wisconsin, 1978.

Cell, Charles P., and Donald Johnson. "Wisconsin Farmers in 1977: A Regional Profile." *Population Notes.* Dep. Rural Soc., University of Wisconsin, Madison, 1978.

Johnson, Donald E., and Keith Warner. *Wisconsin Farm Organization and Cooperatives: Membership and Patronage.* University of Wisconsin Agr. Exp. Sta. Bull. 581, 1966.

Hirschman, A. O. *Exit, Voice and Loyality.* Cambridge, Mass.: Harvard University Press, 1970.

Morrison, Denton E. *Farmers' Organizations and Movements Research Needs, and a Bibliography of the United States and Canada.* Michigan State University Agr. Exp. Sta. Res. Bull. No. 24, 1970.

Nie, Norman H., and C. Hadlai Hull. *SPSS Batch Release 7.0 Update Manual.* Madison: University of Wisconsin, 1977.

Olson, Mancur. *The Logic of Collective Action.* Cambridge, Mass.: Harvard University Press, 1971.

Wilson, Graham. "Farmers' Organizations in Advanced Societies." *International Perspectives in Rural Sociology,* Howard Newby, ed. New York: John Wiley & Sons, 1978.

Wisconsin Statistical Reporting Service. *1978 Wisconsin Agricultural Statistics.* Madison: Wisconsin Department of Agriculture, 1978.

plained in a regression analysis, nearly two-thirds of this (.10) is explained by a single variable: gross farm income.

If the magnitude of farm operation is important in determining whether one is currently a member of an organization, might it also be important in determining whether a farmer stays in or leaves a particular organization?

This appears to be the case for the NFO, where the variables together account for nearly half of the variance (.441). While the overall pattern of those who remain in the NFO emphasizes magnitude, a third of the variance is explained by their agreement with NFO policies (.17), as opposed to those who quit. This is in contrast to FB and FU, where there are no observed differences between remaining and former members on the organization's policies.

The magnitude variables together explain .14 of the variance between current and former FB members. The statistically important variables included in the description of remaining Farm Bureau members are virtually all directly related to magnitude of the farm operation.

The explanation of those who remain Farmers Union members follows a pattern similar to FB members who remain with .18 of the variance explained. The variables are essentially the same, with most directly tapping the magnitude dimension.

Regional Analysis

Also important in the decision to join a particular organization is the location of the farmer. Marked differences in organizational membership by region can be seen from the data reported in table 6 (see also Cell and Johnson). It would appear, from talking with current and former officials of these organizations, that history has had a strong impact on these regional variations. The Farmers Union entered Wisconsin in the northwestern third of the state from its strong Minnesota base. Consequently, it has been much stronger in the northwestern regions of the state. The Farm Bureau, in contrast, entered Wisconsin from the South, fueled by the very strong Illinois Bureau. It has not penetrated the northern or central regions of the state heavily, apparently preferring to concentrate on the larger farmers in the southern part of the state. In its efforts to capture a controlling share of the market, the NFO also has tried to concentrate on larger farmers, thus tending to cover the same areas as the FB. Region plays little role in determining who leaves these farm organizations, at least for the FB and FU. However, for the NFO, quitters have been much more likely in the central, north-central, and northwest regions, all among the least productive farming areas. (Those regions where NFO joiners were more likely to stay were among the most productive: east-central, south-central, and west-central.)

Conclusion

These data suggest that the magnitude of the farm operation is an important factor in the decision to join a farm organization. However, the decision regarding which organization to join is somewhat more complex. Because farm organizations have been differentially active in different parts of the state, region plays an important intervening role. While ideological commitment plays some role in the original decision to join and remains important in the maintenance of NFO membership, it appears to be of little consequence for the FU and FB. For the FU and FB, the most important factor in sustaining membership over time has been their continued ability to deliver selective incentives to members. This ability to sustain membership is more likely to apply to farmers who maintain large-scale operations.

Thus, with the exception of the original decision to join, these data provide little support for the views of Wilson on the importance of ideological commitment. They do, however, suggest that Olson may be on the right track. The NFO, with its apparent lack of selective incentives and higher political

Table 6. Farm Organization Membership and Region

Membership in Farm Organizations	Region									No. of Members in Sample
	NW	NC	NE	WC	C	EC	SW	SC	SE	
					(%)					
Farm Bureau	6	7	6	13	6	17	18	17	11	(150)
Farmers Union	23	14	3	26	4	6	13	9	3	(78)
National Farmers Organization	3	6	3	4	6	21	12	21	6	(34)
										(262)[a]

[a] This panel double counts thirty-two cases who are members of two organizations. Because of the double count, no statistics are provided. (If a fourth category were added for members of two or more organizations, χ^2 significance would equal .0004.)

Table 5. Index of Farmer Alienation

Item	Item Correlation with Index	TAU Correlation with Nonmembers[a]
1. This world is run by a few people in power and there is not much the little guy can do about it.	.48	.06
2. Farm prices are largely determined by large processors and retailers.	.35	−.002
3. If their situation is to improve, farmers must gain more control of the processing and retailing of farm products.	.34	.11**
4. If the economic situation for farmers continues like it is now, in a few years the family farm will be replaced by large farms run by hired labor.	.32	.06
5. Large supermarket chains tend to use their buying power to hold down farm prices.	.30	−.01
6. I have little chance of protecting my personal interests when they conflict with those of strong pressure groups.	.30	−.07
7. Government price programs are actually the cause of the present price problems.	.26	.10*
8. Most of the time I do not really feel like a member of this community.	.27	.12**
9. Collective bargaining cannot work in agriculture because farmers with different kinds of products can never agree with each other.	.24	.15***
10. If you want to solve agriculture's problems, it's the production and marketing system as a whole that needs to be changed.	.24	.05
11. It will never be possible to organize enough farmers and farm production to make collective bargaining successful.	.15	.12**
12. The average citizen *can* have an influence on government decisions.	−.14	−.03
Alpha Reliability Coefficient = .64		
	Mean	
1) Not Member Any Farm Organization	2.38	
2) Current Member FU	2.46	
3) Current Member Any Farm Organization	2.54	
4) Current Member FB	2.56	
5) Current Member NFO	2.70	

[a] Single asterisk means significant at the .05 level; ** is significant at the .01 level; *** is significant at the .001 level.

members indicated that they are not getting any specific benefits from the FB. Only 25% saw disagreement with FB policies as having some level of importance in their decision to leave. Forty-seven percent of former FU members considered the lack of specific benefits important in their leaving, while only 20% felt their disagreement with FU policies had any importance. The reasons for NFO members leaving were basically reversed: 70% saw their disagreement with NFO policies as having some level of importance, whereas only 50% found the lack of specific benefits as significant.

Thus, the composite picture of these findings suggests that for the FB and FU, the role of specific benefits, most of which are types of Olson's selective incentives, plays the most important part in farmers remaining members, as well as deciding to leave the organizations. This is in contrast to the NFO where agreement with policies appears to be more important than specific benefits in the decision to join, stay, or leave. For all three organizations, the agreement with policies and programs and the desire to help promote them were more important in the original decision to join than were economic factors. Thus, while Wilson's emphasis of political and policy questions may have some merit in the original decision to join, it would appear that once a person becomes a member, selective incentives, especially of an economic nature, become paramount to him.

Magnitude of Farm Operation

In addition to the impact of selective incentives on farm organization membership, these data reveal that the magnitude of farm operation is strongly related to farm organization membership.

Strong relationships exist between a number of variables that measure the size of the farm operation and whether or not one is currently a member, or a past member, of a farm organization. Most of these variables, such as income statistics, acreage size, number of dairy cows, and absence of work off the farm, appear to be merely different ways of tapping the same dimension: magnitude of farm operation. Although only .17 of the variance is ex-

Table 4. NFO Index of Support to Change Market System (Pro-Collective Bargaining)

Item	Item Correlation with Index	TAU Correlation with NFO Members[a]
1. If the economic situation for farmers continues like it is now, in a few years the family farm will be replaced by large farms run by hired labor.	.49	.01
2. If their situation is to improve, farmers must gain more control of the processing and retailing of farm products.	.39	−.05*
3. It would be to farmers' advantage to gain control over one of the large retail food chains.	.36	−.06**
4. If farmers can make their bargaining power felt, they can only do so if they can cut off the available supply to the processor.	.31	.05*
5. Farm prices are largely determined by large processors and retailers.	.32	.03
6. Large supermarket chains tend to use their buying power to hold down farm prices.	.28	.06**
7. If you want to solve agriculture's problems it's the production and marketing system as a whole that needs to be changed.	.24	.04*
8. A farm organization should have only operating farmers as members.	.19	.06**
9. Food processors and retail chains should not be allowed to own farm production facilities such as cattle feeding lots, dairy herds, and vegetable farms.	.19	.02
10. Collective bargaining cannot work in agriculture because farmers with different kinds of products can never agree with each other.	−.17	−.17***
11. It will never be possible to organize enough farmers and farm production to make collective bargaining successful.	−.14	−.13***
12. Farmers cannot count on government assistance in solving their marketing and price problems.	.07	.05*
Alpha Reliability Coefficient = .63		
	Mean	
1) Member NFO (National Farmers Organization) Now	2.00	
2) Former Member NFO	2.34	
3) Not Member Any Farm Organization	2.46	
4) Never Member NFO	2.51	

[a] Single asterisk means significant at .05 level; ** is significant at .01 level; *** is significant at >.0000.

These services included various forms of insurance as well as more general forms of advice on planting, harvesting, and marketing. Seventy percent of the FB members obtained at least one form of insurance from the FB insurance companies and nearly 50% of the FU members did so from FU insurance companies, but only 5% of the NFO members obtained insurance from the FB or FU companies.[5] NFO members were most likely (43%) to obtain marketing advice from the NFO. The NFO provides little in the way of other services. Of those who are not members of any organization, only 8% obtained services from any farm organizations. However, FB members were three times as likely to use the FB-related FARMCO/FS coop as FU or NFO members or those not members of any organizations. FU members were twice as likely to use FU-related CENEX coop as FB or NFO members or those not members of any organization. Higher patronage refunds usually go to those who are members. Especially for farmers with high business volume, this refund differential can make a substantial monetary difference. Similar relationships between farm organization membership and independent coop patronage were not apparent with coops such as Midland, milk marketing, and livestock sale barns. This suggests that joint farm organization membership and coop patronage is economic rather than ideological.

Those who had left the organizations were asked to rank the importance of reasons for leaving. The most important reason, indicated by 57% of the former Farm Bureau members, is that they "were not getting any specific benefits from the FB." When combined with the specific selective benefit item of obtaining insurance more cheaply elsewhere, a total of 80% of the former Farm Bureau

[5] In certain limited circumstances, the farm organizations will provide services to nonmembers. For example, the Farm Bureau will sell life, crop-hail and fire-wind insurance to nonmembers, but one must be a member to obtain auto, health, or comprehensive farm insurance. The Farmers Union will sell all forms of insurance to members and nonmembers alike. Most farmers, whether members or not, patronize one or more coops.

In short, although a scale has been developed which is believed to represent reliably the views of the state Farm Bureau, there is little indication that the members of the Farm Bureau, either present or past are more or less likely to adhere to those views than non-FB members. Further credence is lent to this position by the fact that with the exception of three items indicating Farm Bureau members' desire to reduce government influence in agriculture, there are no significant tau_c correlations on the specific items with FB members. Indeed, the item (5), on free markets most central to the Farm Bureau's basic position on free market competition, has the lowest correlation of all the items—.001. Thus, the rationale for membership in the Farm Bureau will have to be found elsewhere.

In table 3, similar results can be seen for past and current members of the Farmers Union. Again there are no significant differences between whether one is or has never been an FU member of between current and former members of the FU, although the mean for former members is slightly higher. Conversely, farmers who are not currently members of any farm organization have a lower mean than any other group, suggesting that, if anything, their views may be closer to the FU position of government intervention and greater control of the market than FU members, past or present. Also, with the exception of two items which are barely significant (at the .05 level), there is virtually no correlation between FU positions and the attitudes of FU members toward these policies.

Conversely, the data in table 4 show that former and, especially, current members of the National Farmers Organization are more likely to hold attitudes in line with the NFO's policies than nonmembers of the NFO, whether or not they are or have been members of other organizations. Particularly noteworthy is the significant difference in means between those who have never been members of the NFO and those who were or are now members (2.51 vs. 2.00). Not surprisingly, virtually all of the index items have significant correlations with current NFO members. In short, it would appear that unlike the FB or FU, members of the NFO are more likely to agree with the positions of the NFO than nonmembers.

The Farmer Alienation Index in table 5 indicates that farmers who are not currently members of farm organizations are more likely to be alienated in terms of agricultural policy options and life style than are members. Conversely, members of the FB and NFO and, to a lesser extent, FU members, are less likely to be alienated. This supports Wilson's position.

Selective Incentives

In follow-up interviews farmers were asked what services they obtained from farm organizations.

Table 3. Farmers Union Index of Support for Government Intervention (Support Control of Market)

Item	Item Correlation with Index	TAU Correlation with FU Member[a]
1. If their situation is to improve, farmers must gain more control of the processing and retailing of farm products.	.45	−.03
2. It would be to farmers' advantage to gain control over one of the large retail food chains.	.43	.06*
3. Large supermarket chains tend to use their buying power to hold down farm prices.	.35	.03
4. If the economic situation for farmers continues like it is now, in a few years the family farm will be replaced by large farms run by hired labor.	.35	.02
5. Farmers will always need some type of farm price support program.	.29	.05
6. This world is run by a few people in power and there is not much the little guy can do about it.	.29	.02
7. If farmers can make their bargaining power felt, they can only do so if they can cut off the available supply to the processor.	.27	.02
8. The government should provide a food grain reserve to help stabilize prices for the farmer.	.26	.07*
9. If you want to solve agriculture's problems, it's the production and marketing system as a whole that needs to be changed.	.21	.03
Alpha Reliability Coefficient = .64		
	Mean	
1) Not Member Any Farm Organization	2.02	
2) Never Member FU	2.07	
3) Member FU Now	2.08	
4) Former Member FU	2.14	

[a] Asterisk denotes significance at .05 level.

Table 1. Changes in Farm Organization Membership

	Members of a Farm Organization				Percentage of 1977 Sample Who Have Dropped Their Membership	
	1966		1977		(100% is Number Ever Joined a Given Organization)	
	(No.)	(%)	(No.)	(%)	(No.)	(%)
Farm Bureau	106	16	148	24	88	37
Farmers' Union	73	11	80	13	44	36
National Farmers' Organization	92	14	37	6	72	68

and FU has increased since a similar survey in 1966 (Johnson and Warner); the NFO has experienced a considerable decline in membership (table 1). Two-thirds of farmers who have ever been NFO members have quit the NFO, while only about a third of those who have ever been members of the FB and FU have quit. On the question of the ability to sustain membership, Olson appears to be correct.

Agricultural Policies and Farm Operators' Opinions

The data in table 2, the Index of Free Market Support, show no significant differences in means of paired relationships determining whether one has been or is a member of the Farm Bureau, or whether or not a farmer is a member of any farm organization.[4] The mean is significantly different only when comparing those who are or have been FB members with those who have never been members of the FB. This difference undoubtedly is due to the fact that NFO members with clear views which often oppose FB policies are included here, along with FU members and others who are not current members of other groups or have never been members of the FB.

[4] A .05 level, 2-tailed test. This is the minimum significance level used for all tests of mean differences in tables 2–5.

Table 2. Farm Bureau Index of Free Market Support (Anti-Collective Bargaining, Anti-Government Intervention)

Item	Item Correlation with Index	TAU Correlation with FB Members[a]
1. Government price programs pose a serious threat to the freedom of the farmer.	.46	.09*
2. Government price programs are actually the cause of the present price problems.	.41	−.01
3. Farmers cannot count on government assistance in solving their marketing and price problems.	.29	.01
4. Collective bargaining cannot work in agriculture because farmers with different kinds of products can never agree with each other.	.25	−.004
5. The marketing power of farmers can best be achieved by the use of the market price system. Under this system, supply and demand become the primary factors in determining the true market level for agricultural commodities.	.24	.00
6. Farmers always will need some type of farm price support program.	−.24	−.10*
7. It will never be possible to organize enough farmers and farm production to make collective bargaining successful.	.19	−.02
8. The government should provide a food grain reserve to help stabilize prices for the farmer.	−.19	−.07*
Alpha Reliability Coefficient = .57		
	Mean	
1) Not Member Any Farm Organization	2.56	
2) Former Member FB	2.56	
3) Member FB Now	2.58	
4) Never Member FB	2.68	

[a] Asterisk denotes significance at .05 level.

more with Democratic Party policies, and the FB with Republican Party policies (p. 33). In any case, he argues that farmers in the United States do have a choice. Thus, in the spirit of Hirshman's notions of exit, voice, and loyalty, farmers in the United States will seek the group most suited to their political benefits, rather than develop rancorous politics within the organization (p. 42). In contrast to Britain, the lack of political debate among members in U.S. farm organizations should not be seen as an absence of interest in farm policies and politics but rather as a function of homogeneity of attitudinal beliefs on agricultural policies.[2]

If Wilson is correct, the data should show that the attitudes of members of any given farm organization should correspond closely to the policies of the state organization. This would be in contrast to farmers who are not members of that organization.

Data from a recent survey of Wisconsin farmers conducted by the Department of Rural Sociology at the University of Wisconsin sheds some light on this debate over motivation for membership. Four dimensions are examined: attitudes toward agricultural policies, the impact of selective incentives, the magnitude of the farm operation, and regional location. The first two dimensions provide a direct test of Olson's and Wilson's perspectives. The latter two dimensions provide additional levels of explanation of farm organization membership. Specifically, these data show that the larger the farm operation, the more likely it is that a farmer will join an organization. Location is important in Wisconsin because it points to the importance of historical factors in determining which organization farmers are more likely to join.

Methodology

The data presented here were gathered as part of a questionnaire mailed to 1,000 Wisconsin farm operators in January-March 1978, and through follow-up field interviews conducted in March–April 1979. The reported data refer to the 1977 calendar year. The sample was selected randomly from lists of farmers furnished by local township tax assessors. About 62% of those sampled returned usable questionnaires.[3] Follow-up interviews were conducted with about 200 of those who completed the questionnaires. All data are from the questionnaire except for items on the use of farm organization services, coop patronage, and decisions to join or leave the farm organizations, which are from the interview.

To measure correspondence of farmers' attitudes with farm organizations' agricultural policies, farmers were asked to rank their level of agreement, on a scale of one to five, with statements relating to farm life and agricultural policy. Most of these items were designed to tap the views of one or more of the state farm organizations on agricultural policy. These views were determined via consultation with observers in the University, an analysis of the organizations' literature, and discussion with representatives of the organizations.

In addition to the conceptual division of the items described above, the items were examined statistically via an intercorrelation matrix to determine which were more likely to be empirically interrelated. These two methods were combined to produce three scales, each of which is believed to be a reasonable approximation of policies of the FB, FU, and NFO. Means were calculated for each of four groups: (*a*) the current members of a given organization (FB, FU, or NFO), (*b*) former members of the organization, (*c*) farmers who have never been members of that organization, and (*d*) those who are not currently members of any farm organization. This latter category overlaps with parts of groups 2 and 3, but it is useful in distinguishing the effects of a current lack of any organizational affiliation.

In addition to these three scales of policy items, another grouping appeared. This group reflected a negative reaction to most of the policy options offered by the farm organizations, as well as a general dissatisfaction with community life and a feeling of powerlessness. To distinguish this from traditional alienation indexes, it is called a Farmer Alienation Index. An extension of Wilson's argument would suggest that the 62% of the sample who are not currently members of any organization are those who generally are more alienated, and thus do not find palatable any of the farm organization alternatives.

Scale means were calculated for five groups: farmers not currently members of any organization, members of each of the three organizations, and a composite mean for all three member groups. These means were tested for reliability with the SPSS Alpha Reliability program (Nie, pp. 58–102). In all cases, the reliability was significantly above the accepted minimum of .4 (.55 or more).

Regional analysis was conducted on the basis of regions used by the Department of Agriculture for crop-reporting purposes. Essentially, the intention was to divide Wisconsin's counties into nine regions, which emphasizes similarities within regions, especially in terms of soil and climatic conditions.

Findings

There is a substantial difference between organizations in their abilities to sustain membership. The percentage of farmers who are members in the FB

[2] Wilson does note political differences between national leadership and state organization, especially with the NFO and the FB (pp. 40–41). However, because we are testing his theories only in terms of Wisconsin, whose primary agricultural interest is dairying, this issue need not concern us here.

[3] Through telephone interviews, limited information was gathered on 38% of the nonrespondents. Little difference between this group and the group who completed questionnaires (616) is apparent.

Selective Incentives versus Ideological Commitment: The Motivation for Membership in Wisconsin Farm Organizations

Charles P. Cell

A common explanation for farmers' problems is the claim of poor organization (Morrison). In a 1965 survey of Wisconsin farm operators, Johnson and Warner determined that only 38% of farm operators were then members of major farm organizations. Twenty-two percent had been members previously, and 40% had never joined. The research reported here indicates that the overall percentages remain virtually unchanged a decade later. It appears, however, that the National Farmers Organization (NFO) has lost membership, while the Farm Bureau (FB) and Farmers Union (FU) have gained members relative to the total number of farmers in Wisconsin. Why do some farmers join, others quit, and still many others never join any of these organizations?

A debate has developed recently regarding the motivation for membership in farm organizations. This debate stems from the work of Olson. Although Olson is concerned with broad issues of how various sizes and types of groups function, the focus here is on his analysis of how large-scale or "latent" groups, without coercive abilities, function and gain commitment from their members. This is the focus because the farm organizations considered here all fit within this category.

Olson argues that large-scale organizations working toward the acquisition of resources that will benefit the entire constituency (i.e., all farmers) will not sustain membership. The incentive to belong is weak because all potential constituents including nonmembers will benefit if the organization is successful. However, if they offer "selective incentives," such as low-cost insurance plans and greater patronage refunds which benefit only members, then the organization is more likely to sustain its membership over time. Although this perspective may not explain the initial reasons for joining an organization (Cell), it does attempt to predict which farm organizations will sustain membership in the long run, and why.

Thus, Olson contends that the political policies and lobbying programs of the FB and FU are not significant factors in drawing support from farmers. However, he argues that selective economic benefits (e.g., low-cost insurance, milk testing, and higher patronage refunds from related coops) gained by joining should account for membership in these organizations. This, he believes, is in contrast to the NFO, which does not have selective incentives. The central goal of the NFO is to improve market conditions by gaining a commanding control of production through collective bargaining agreements. Olson believes that these benefits, should the NFO be successful, would not be selective, but rather all farmers would benefit.[1]

If Olson is correct, the data should show little difference of opinion between members and nonmembers of the State Farm Bureau and the Farmers Union on political and policy issues. NFO members would be expected to have a higher level of commitment to NFO policies. These data also should reflect the fact that the NFO has been less able to sustain its membership and that selective incentives are an important motivation for sustaining membership in the Farm Bureau and Farmers Union, as opposed to the NFO.

Wilson attacks Olson's position. "Olson's theory seems to explain neither the differences in the proportion of potential farmers recruited by pressure groups nor the number of such organizations which compete for his favours" (p. 33). If selective incentives are so important, Wilson asks why twice the number of British farmers join Britain's only farm organization than do American farmers who have multiple choices and selective incentives? This is particularly incongruous Wilson argues when one remembers that Britain's welfare state presumably makes the need for such benefits of selective incentives even less likely.

In contrast to Olson, Wilson sees farm organizations fundamentally as pressure groups (p. 44). This, he notes, is particularly true in the United States with the FU and NFO usually identified

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[1] There is some basis for arguing that when a farmer signs a collective bargaining agreement with the NFO he is getting a selective incentive. If the market price of the product is less than the contract price at the time the product is sold, the farmer benefits. Unfortunately for the NFO, it also can work the other way.

ed. K. Brenner and A. H. Meltzer. Amsterdam: North-Holland Publishing Co., 1976.

Morzuch, B. J., R. D. Weaver, and P. G. Helmberger. "Wheat Acreage Supply Response under Changing Farm Programs." *Amer. J. Agr. Econ.* 62(1980):29–37.

Muth, John F. "Rational Expectations and the Theory of Price Movements." *Econometrica* 29(1961):315–35.

Orcutt, G. H. "Actions, Consequences, and Causal Relations." *Rev. Econ. and Statist.* 34(1952):305–13.

Peltzman, S. "Toward a More General Theory of Regulation." *J. Law and Econ.* 19(1976):211–40.

Rausser, G. C., and D. P. Stonehouse. "A Quarterly Econometric Model of the Canadian Dairy Industry with Endogenous Policy Variables." Montreal: Agriculture Canada; Policy, Planning, and Evaluation Branch. Work. Pap., Aug. 1978.

Simon, H. A. "Causal Ordering and Identifiability." *Studies in Econometric Method*, eds. W. C. Hood and T. C. Koopmans. New York: Cowles Commission Monograph No. 14, 1953.

Sims, C. A. "Money, Income, and Causality." *Amer. Econ. Rev.* 62(1972):540–552.

Stigler, G. J. "The Theory of Economic Regulation." *Bell J. Econ. and Manage. Sci.* 2(1971):3–21.

Strotz, R. H., and H. Wold. "Recursive versus Non-Recursive Systems: An Attempt at Synthesis." *Econometrica* 28(1960):417–27.

Theil, H. *Principles of Econometrics*. New York: John Wiley & Sons, 1971.

Weaver, R. D., and Amy Krainik. "Policy Control of Corn Acreage: A Re-Examination." Dep. Agr. Econ. Staff Pap. No. 23, Pennsylvania State University, Sep. 1979.

Table 1. Results of Tests of Exogeneity: F-statistics

Dependent Variable	Wheat Acreage Planted				Wheat Allotment			
Null Hypothesis[a]	1	2	3	4	1	2	3	4
State	$F(4,5)$	$F(1,5)$	$F(1,5)$	$F(2,5)$	$F(4,5)$	$F(1,5)$	$F(1,5)$	$F(2,5)$
North Dakota (SW)[b]	2.42	1.45	.84	.85	1.47	.07	.32	.20
South Dakota (SW)	2.04	.76	.01	.48	1.87	.34	.44	.37
Montana (SW)	.34	.14	.76	.38	.53	.80	.64	.37
Colorado (WW)	.25	.71	.03	.36	.16	.007	.33	.22
Kansas (WW)	4.02	11.53	2.83	5.79	.04	.008	.002	.007
Montana (WW)	.70	.32	.11	.99	.27	.07	.21	.36
Illinois (WW)	2.12	.02	1.06	.75	5.38	.05	6.05	3.09
Indiana (WW)	2.21	1.46	1.32	2.44	6.85	.38	16.25	8.14
Nebraska (WW)	1.69	.55	4.18	2.23	1.48	2.99	.03	1.94
Ohio (WW)	33.26	3.69	51.07	49.88	10.39	30.71	1.75	15.58
Oklahoma (WW)	11.15	23.23	16.13	16.57	.43	1.06	.04	.63
Texas (WW)	1.39	2.36	2.95	1.69	.31	.05	.19	.25
Washington (WW)	6.15	3.29	13.83	7.05	1.81	1.09	.40	1.86
United States (WW)	1.55	1.35	3.88	2.29	1.39	.03	.22	.33

[a] Null hypotheses are as follows for the model $Y_t = \alpha + \beta_1 X_t + \beta_2 X_{t-1} + \beta_3 X_{t+1}$:

Column No. 1 $\alpha = \beta_1 = \beta_2 = \beta_3 = 0$;
Column No. 2 $\beta_2 = 0$;
Column No. 3 $\beta_3 = 0$;
Column No. 4 $\beta_2 = \beta_3 = 0$.

[b] SW indicates spring wheat, WW indicates winter wheat.

Table 2. Critical Values for F-Statistics

Degrees of Freedom	Significance Levels			
(v_1, v_2)	.25	.10	.05	.01
(4, 5)	1.89	3.52	5.19	11.4
(1, 5)	1.69	4.06	6.61	16.3
(2, 5)	1.85	3.78	5.79	13.3

positive feedback was found for Oklahoma. These later results suggest that the allocation of allotments to states may have been endogenous and responsive to recent trends in plantings in the states. For the U.S. aggregate data, a negative relation was found between current allotment and lagged acreage, perhaps reflecting counter-cyclical effects of the allotment.

Although these results should not be interpreted as definitive, they do suggest that the temporal ordering of the relation between allotments and acreage is not homogenous across states and involves, in several states and possibly at the U.S. aggregate level, lags in response of acreage planted to the allotment, and vice-versa.

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References

Basman, R. L. "The Causal Interpretation of Non-Triangular Systems of Economic Relations." *Econometrica* 31(1963):439–48.

Feige, E. L., and D. K. Pearce. "Economically Rational Expectations: Are Innovations in the Rate of Inflation Independent of Innovations in Measures of Monetary and Fiscal Policy?" *J. Polit. Econ.* 84(1976):499–522.

Gardner, B. L. "Futures Prices in Supply Analysis." *Amer. J. Agr. Econ.* 58(1976):81–84.

Garst, G. D., and T. A. Miller. "Impact of the Set-Aside Program on the U.S. Wheat Acreages." *Agr. Econ. Res.* 27(1975):30–37.

Geweke, John. "Testing the Exogeneity Specification in the Complete Dynamic Simultaneous Equation Model." *J. Econometrics* 7(1978):163–85.

———. "Wage and Price Dynamics in U.S. Manufacturing." *New Methods in Business Cycle Research: Proceedings from a Conference*. Minneapolis, Minn.: Federal Reserve Bank of Minneapolis, 23 Oct. 1977.

Granger, C. W. J. "Investigating Causal Relations by Econometric Models and Cross-Spectral Methods." *Econometrica* 37(1969):424–68.

Harrison, G. A., and E. O. Heady. *Acreage Diversion Response under the 1961–70 Feed Grain Programs*. Center for Agricultural and Rural Development Rep. No. 71, Iowa State University, March 1977.

Houck, J. P., et al. *Analyzing the Impact of Government Programs on Crop Acreage*. Washington, D.C.: USDA ERS Tech. Bull. 1548, Aug. 1976.

Just, R. E. *Econometric Analysis of Production Decisions with Government Intervention: The Case of California Field Crops*. Department of Agricultural Economics, Giannini Foundation Mono. 33, University of California, Berkeley, 1974.

Lindbeck, A. "Stabilization Policy in Open Economics with Endogenous Politicians." *Amer. Econ. Rev.* 66(1976):1–19.

Lucas, R. E. "Econometric Policy Evaluation: A Critique." *The Phillips Curve and Labor Markets,*

Instantaneous causality between X and Y would require, in addition to (4),

$$\theta^{\circ}_{t-j} = 0 \quad \forall \quad j = 1, \ldots, \infty \tag{6}$$

Finally, if the restrictions in equation (2) as well as those in (4) are rejected, then evidence exists which is consistent with the hypothesis of feedback between X and Y.

To summarize, the two regressions (1) and (5) present a basis for a two-step procedure of hypothesis testing concerning the temporal ordering of the relation between X and Y. In the above discussion, we began with equation (1) and proceeded conditionally to test parameter restrictions on equation (5). However, the choice of this starting point was arbitrary. By an analogous procedure, the process of inquiry could begin with equation (5).

Before proceeding we must consider the usefulness and necessary alterations of the proposed methodology in a context which is not bivariate. Certainly, if there existed a third variable Z, its relation with Y must be specified under the null hypothesis. If both Z and X are hypothesized to cause Y, then Z should be incorporated in (1). Alternatively, if Z is hypothesized to determine simultaneously X and Y, equation (1) would be a misspecification. Instead, the hypothesis of Z's exogeneity with respect to X or Y should each be investigated with appropriate variations of (1). Thus, in a multivariate system such as a national or international commodity market, the test of exogeneity can not be done with a bivariate model such as (1), but instead must be conducted in the context of a fully specified market model, see Geweke (1978).

In the present paper, the question of interest is the exogeneity of wheat acreage allotments in the determination of wheat acreage planted. Past studies have maintained the hypothesis that acreage planted is determined by a number of market, climatological, and policy factors. For example, we might postulate that at an aggregate level, supply of acreage could be written as a function of relative expected output prices, input prices, indexes of fixed factors or other technological constraints, and the wheat acreage allotment. However, under the null hypothesis that wheat acreage planted is determined by an exogenous wheat allotment, the above bivariate test procedure may be employed. Such a hypothesis would be consistent with simultaneity of allotments and planned acreage so long as actual acreage planted deviated from the plan. Specifically, the exogeneity of wheat acreage allotments to wheat acreage planted was investigated during the quota program (1950, 1954–64) at the state (for thirteen major wheat states) and national levels of aggregation. We focus on the quota program years because during these years allotments were designed specifically as constraints on acreage planted. Although there were years during which other programs were operative (e.g., marketing certificate programs, 1965–70; or the set-aside programs, 1971–73) no a priori basis was apparent for the justification of the hypothesis that parameters were stable across different government programs. Furthermore, Morzuch, Weaver, and Helmberger; and Weaver and Krainik present evidence which supports the hypothesis that parameters changed across government programs. Thus, we choose to employ a small sample (1954–64) rather than a larger, perhaps heterogenous one which might involve inappropriate parameter restrictions.[1] Specifically, models which are consistent with equations (1) and (5) are estimated with a single one-period lead and a single one-period lag.[2] That is, if we let acreage planted be Y and the allotment be X, and if we follow equation (1), then acreage planted is the dependent variable, and measures of the acreage allotment are the independent variables. Alternatively, when the allotment is the dependent variable, measures of acreage planted are independent variables as noted in equation (3). As discussed above, the temporal ordering of the relation between acreage planted and the allotment is investigated by testing the validity of appropriate leads or lags.

Table 1 reports F-statistics in columns labelled 1 for the empirical versions of equations (1) and (5), which include one lead and one lag. In addition, F-statistics are presented for tests of restrictions discussed above, which allow inference concerning the temporal ordering of the relation between acreage planted and the allotment. Specifically, columns marked 2 indicate the F-statistic associated with the hypothesis that the lag coefficient is zero, while columns marked 3 report tests of a zero restriction on the lead. Columns marked 4 report the F-statistic for a joint test of the restriction that both the lead and the lag are zero.

As results in table 1 indicate, no general conclusion can be drawn concerning the exogeneity of allotments. We see that in North and South Dakota the relation appears to have been instantaneous, while in Montana and Colorado no relation appears to have existed. For the remaining states we find a one-period lag in the relation. Specifically, for Kansas, Illinois, Indiana, and U.S. aggregate data, we find evidence which supports the hypothesis that allotments were exogenous and had a one-period lagged effect on acreage. For Ohio and Washington evidence strongly supports the hypothesis that acreage planted was exogenous to allotments, having a positive, one-period lagged effect. Similar, though weaker, evidence is found for Nebraska, Texas, and the United States. Strong evidence of

[1] Geweke (1977) reports results of application of the methodology to small samples, which lead him to the tentative conclusion that the exogeneity results appear robust.

[2] We have followed Geweke's 1977 suggestion that an appropriate criterion for selection of the length of lag is the convergence of the residual to a white noise process. In all cases, inclusion of one lead and one lag was sufficient to accomplish this.

A Test of the Temporal Exogeneity of Allotments and Acreage Planted

The importance of the classification of variables as either endogenous or exogenous was noted above. We will adopt Granger's definitions of causality which underlie what Sims has called exogeneity. Specifically, Granger has emphasized that the effect of a change in an exogenous variable on an endogenous variable must take time. (This differs from the orientation taken in earlier literature on simultaneity and instantaneous causality which largely ignored the importance of time in causation; see, e.g., Strotz and Wold, Basman, Simon, and Orcutt.) That is, at a theoretical level exogeneity is only meaningful if time passes while cause takes effect. For example, the statement X causes Y makes sense only if we mean X_t causes $Y_{t+\delta}$ where δ is a positive, though possibly infinitely small, increment.

To proceed, it is useful to establish the set of possible relations between X and Y which may exist at a theoretical level as well as those which may be identified at an empirical level. As illustrated in figure 1, we have three possible hypotheses concerning relations between X and Y: (*a*) X_t is exogenous to $Y_{t+\delta}$ (indicated by single lined arrows); (*b*) Y_t is exogenous to $X_{t+\delta}$ (indicated by double lined arrows); or (*c*) X_t is exogenous to $Y_{t+\delta}$, and $Y_{t+\delta}$ is exogenous to $X_{t+\delta+1}$; or Y_t is exogenous to $X_{t+\delta}$, and $X_{t+\delta}$ is exogenous to $Y_{t+\delta+1}$. The latter possibility is labeled feedback and would be represented by a path of causation which alternates between single and double lined arrows. In addition to one of these relations between X and Y, the possibility that no relation exists represents a fourth hypothesis which must be considered. Consistent with this possibility would be the simultaneous occurrence of X_t and Y_t, both determined by a common vector $\mathbf{Z}_{t-\delta}$.

Unfortunately, stepping from a theoretical concept to an empirical setting requires measurement of X and Y over discrete intervals. In such a case, it is possible that X_t is exogenous to $Y_{t+\delta}$; however, if the time series X and Y can be observed only discretely at intervals of an equal length which exceeds δ, then the effect of X on Y would appear to be instantaneous. Likewise, if Y_t is exogenous to $X_{t+\delta}$; however, the observation interval exceeds δ, then the effect of Y on X would appear to be instantaneous. In either case of instantaneous causality, no inference can be made concerning the direction of causation in the absence of observations taken at equal intervals of length less than δ. However, we may conclude that in an empirical context the concept of instantaneous causality between X and Y would be consistent with the Granger notion of the temporal ordering of cause and effect.

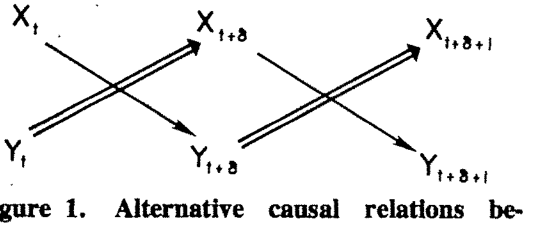

Figure 1. Alternative causal relations between X and Y

As Granger has shown, these definitions provide the basis for a convenient empirical test of a hypothesis of exogeneity. We will review briefly these techniques and their usefulness for investigating the exogeneity of allotments to acreage planted, the hypothesis maintained by past acreage supply studies.

To begin, consider the case where the relation between X and Y is bivariate; i.e., simultaneous determination by other factors, $\mathbf{Z}$ is ruled out. Suppose that we pose as a null hypothesis that in such a bivariate system, X_t is exogenous to $Y_{t+\delta}$. It follows that at any time t, Y cannot be determined by X and also determine X. The empirical analog of this implication (Y is not exogenous to X) of the null hypothesis is that the partial correlation between any future X and current Y will be zero. Translating this into a regression context, the null hypothesis implies that the coefficients of any future $X_{t+\delta}$ included in a regression of Y_t on $(X_t, X_{t+\delta})$ would be zero. Stating this explicitly, we may employ the following equation:

$$(1)\qquad Y_t = \phi(F)X_t + \theta(B)X_t + \gamma X_t + \epsilon_t,$$

where $\phi(F) = \sum_{j=1}^{\infty} \phi_{t+j}F^j$; $\theta(B) = \sum_{j=1}^{\infty} \theta_{t-j}B^j$; F, B are forward and backward shift operators, respectively; and $\epsilon_t \sim N(0,\sigma^2)$. Under the null hypothesis, X causes Y, or (as argued above), equivalently, Y does not cause X,

$$(2)\qquad \phi_{t+j} = 0 \quad \forall \quad j = 1, \ldots, \infty.$$

In addition, the null hypothesis X causes Y instantaneously would require

$$(3)\qquad \theta_{t-j} = 0 \quad \forall \quad j = 1, \ldots, \infty.$$

The alternative hypothesis to X is exogenous to Y is a composite of two possibilities: (*a*) Y is exogenous to X, or (*b*) no relation between X and Y exists. To discriminate between these possibilities, we may proceed conditionally upon the rejection of the restrictions in (2) and test as a null hypothesis the statement that Y_t is exogenous to $X_{t+\delta}$ versus the alternative that Y_t is not exogenous to $X_{t+\delta}$. However, the only inference consistent with the rejection of the restrictions in (2) and this latter alternative is that no relation exists between X and Y. By an argument similar to that presented above, the hypothesis Y causes X, or, equivalently, X does not cause Y implies

$$(4)\qquad \phi^{\circ}_{t+j} = 0 \quad \forall \quad j = 0, \ldots, \infty$$

in the regression:

$$(5)\qquad X_t = \phi^{\circ}(F)Y_t + \theta^{\circ}(B)Y_t + \beta^{\circ}Y_t + \epsilon^{\circ}_t.$$

The Causal Linkage of Control Policy and Its Targets: The Case of Wheat

Robert D. Weaver

Measurement of the impact of a policy instrument (I) on a target variable (X) which is the object of control traditionally has relied upon the hypothesis that I is exogenous to X. Given this hypothesis, a reduced form equation relating X to I is specified and estimated. However, this specification ignores the fact that the level at which the instrument I is set and the desired level of the variable X are both chosen by the policy maker in an attempt to optimize some criteria. Thus, just as inputs, outputs, and, typically, profits are determined endogenously by the firm, the instrument I and the target level for X are chosen simultaneously by the policy makers. In other words, policy instruments, like prices, may be endogenous at the market level, determined by exogenous factors considered by policy makers, although "taken by" or exogenous to individual producers.

Despite the intuitive appeal of this proposition, economists only recently have acknowledged its implication for the measurement of impact multipliers employed in policy design (Lindbeck, Feige and Pearce, Sims). If I is endogenous and determined simultaneously with X, direct estimation by ordinary least squares (OLS) of an equation relating X to I would result in inconsistent estimates (Theil). Unbiased estimates of the impact multipliers can only be achieved through a linkage of the estimation procedure to the theoretical specification of the system in which the instruments and targets are related. In the firm's case, as in the policy maker's, this sytem is the necessary condition for optimal choice of instruments, given the objectives of and the constraints on its choices.

At an empirical level, the validity of the hypothesis is more complicated. Clearly, if the chosen target level of X is not achieved or observed, then although planned X and the level of I may be simultaneous, actual X and I may not be. However, even in such a case the endogeneity of I implies that feedback between I and X may exist as past levels of X influence the choice of current I. Thus, at an empirical level we may conclude that alternatives exist to the hypothesis that I is exogenous to X as maintained in past literature (Lucas; Rausser and Stonehouse). Despite its importance for model specification, the validity of hypotheses concerning endogeneity or exogeneity of variables is difficult to assess. This paper presents and considers the usefulness of a methodology developed in recent literature for assessing the validity of hypotheses concerning the exogeneity of variables such as I to others, such as X. The design of effective and least-cost policies for the control of acreage planted to crops has relied on policy impact multipliers estimated under the maintained hypothesis that policy instruments are exogenous to acreage allocations, see e.g., Garst and Miller, or Houck et al. As a case for application, the present paper considers the exogeneity of wheat acreage allotments to wheat acreage planted at the state and national levels of aggregation during the quota program years 1954–64.

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The Relation between Policy and Its Targets: The Case of Wheat Acreage

One of the most crucial specification decisions which must be made if the relationship among a group of variables is to be quantified is the classification of those variables as either exogenous or endogenous. Past studies of the determinants of acreage allocation and the effects of control policies have maintained the hypotheses that acreage is endogenous and subject to the control of the farmer, and prices (or moments of their subjective distribution) as well as policy instruments are exogenous determinants of acreage. While this classification may be justified by market structure evidence when acreage is measured at the farm level, at aggregate levels its validity is subject to uncertainty. At some level of aggregation, prices or policy may be endogenous to the mechanism which determines them although they may be exogenous to the farmer. Although the validity of a particular specification concerning the exogeneity of prices is an important empirical question, the present paper will focus on the exogeneity of the acreage allotment with respect to acreage planted to wheat.

While it would be difficult to dispute the statement that acreage control instruments such as the allotment are exogenous at the farm level, acreage supply studies most often estimate the relation using aggregate data. For example, national aggregate data is employed by Houck et al., Garst and Miller, and Gardner. Although less typical, state or regional studies have been completed, e.g., Just, Harrison and Heady, Weaver and Krainik, and Morzuch, Weaver, and Helmberger. As has already been noted above, if at any of these levels of aggregation the policy instruments and acreage are simultaneous, then the parameters reported by these studies would be inconsistent estimates.

modity Markets, ed. F. G. Adams and S. A. Klein, pp. 161–88. Lexington, Mass.: Lexington Books, 1978.

Turnovsky, Stephen. "The Distribution of Welfare Gains from Price Stabilization: A Survey of Some Theoretical Issues." *Stabilizing World Commodity Markets*, ed. F. G. Adams and S. A. Klein, pp. 119–48. Lexington, Mass.: Lexington Books, 1978.

goals of increased price stabilization are deemed to be worth the increased program costs of stabilization in a rich country such as the United States; the rate of growth in the export demand for grain, as well as its stability; the policy position with respect to price stabilization of such third parties as livestock producers and grain dealers and millers; and the commercial trade relations of the United States with such superpowers as the Soviet Union and the People's Republic of China. In the process of arriving at a decision with respect to a new and possibly strengthened grain stabilization policy, the U.S. Congress may be expected to gather information, data, and analyses in connection with the above developments, and perhaps many others. This it may be expected to do through the hearing process in which it takes testimony from all parties with an interest in stabilization policy, including the administration in power.

If a team of welfare economists should be invited to present testimony, or if they should offer to present testimony, with respect to grain stabilization policy that is based solely on the logic of consumer and producer surplus, they and their testimony in all likelihood would be destroyed in the hearing process; their destruction would occur as congressmen, unsympathetic to their conclusions and with the aid of legal counsel, inquired into the substance—the empirical content—of their testimony. The discrediting of their testimony might well lead down the following path of questions. "My dear Professor Y, would you please tell the committee how I might measure my consumer surplus for Wheaties, or for all food if you prefer?" "My dear Professor Y, would you please compare the consumer surplus of Mr. A for Wheaties with the consumer surplus of Mr. B for Wheaties?" And finally, "My dear Professor Y, would you please tell the committee which federal agency in this town can provide it with an estimate of the consumer surplus of the nation for the product, Wheaties, or bread, or all food?"

Answers by the economic team to the effect that their analysis was not intended to provide that kind of empirical information would be to no avail. The congressmen would insist upon receiving solid, substantive answers to what they perceived to be reasonable questions. And in holding to this position they would not be entirely wrong. If they are to make policy decisions, in this case a decision with respect to a stabilization policy for the grains, on the basis of testimony presented to them, they must, in turn, be able to use the information provided in testimony to defend their policy decisions on the political hustings. Politicians engaged in the policy decision process demand and get solid, substantive information and analyses which they can use with their constituents; and they are wary, exceedingly wary, of logical niceties, no matter how elegantly presented, which have little or no meaning to their constituents.

In Conclusion

It may be the case that welfare analyses of commodity stabilization schemes have some value in the way of exercising the brain cells of economists. But chess also exercises the brain cells. And chess has the clear advantage of being exactly what it purports to be, namely, a game. Thus, I find it easy to recommend that each economist, who heretofore has busied himself with welfare analyses of commodity stabilization schemes, substitute the playing of chess for his or her welfare analysis activity. If these practitioners of welfare analyses are the skilled problem solvers that neoclassical apologists would have us believe, they should be world class chess players in no time at all, and the clear-cut victories won in tournament play should lift them to utility planes never dreamed of in the mundane field of economics. Meanwhile the rest of us would be spared the time-consuming chore, the cost, of reading each new welfare analysis of a commodity stabilization scheme for fear that we might miss some new piece of usable knowledge if we did not. And finally, this vigorous pursuit of chess as a substitute for welfare analyses of commodity stabilization schemes should provide the same contribution to the making of decisions with respect to national commodity stabilization policy that the former welfare analyses did, namely, a zero amount.

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References

Burmeister, Edwin. "Is Price Stabilization Theoretically Desirable?" *Stabilizing World Commodity Markets*, ed. F. G. Adams and S. A. Klein, pp. 189–91. Lexington, Mass.: Lexington Books, 1978.

Burnstein, Harlan. *Welfare Implications of Instability in Agricultural Commodity Markets*. Dep. Agr. Econ. and Rural Soc. No. 132, Pennsylvania State University, Oct. 1977.

Currie, J. M., J. A. Murphy, and A. Schmitz. "The Concept of Economic Surplus and Its Use in Economic Analysis." *Econ. J.* 81(1971):741–99.

Little, I. M. D. *A Critique of Welfare Economics*. New York: Oxford University Press, 1960.

Marshall, Alfred. *Principles of Economics*, 8th ed. London: Macmillan & Co., 1936.

Samuelson, Paul A. *Foundations of Economic Analysis*. Cambridge, Mass.: Harvard University Press, 1948.

Sarris, A. H., and L. Taylor. "Buffer Stock Analysis for Agricultural Products: Theoretical Murk or Empirical Resolution?" *Stabilizing World Commodity Markets*, ed. F. G. Adams and S. A. Klein, pp. 149–60. Lexington, Mass.: Lexington Books, 1978.

Smith, G. W. "Commodity Instability and Market Failure: A Survey of Issues." *Stabilizing World Com-*

consequences for them, and producers fear a big downswing in farm product prices which can ruin them financially.

Starvation and Stabilization Policy

A less developed country, 20% to 40% of its population living in abject poverty, that has experienced a shortfall in grain production (the basic foodstuff of its people), causing grain prices to rise sharply, has no need for a theoretical welfare study (in which the position and slope of the demand curve for grains are unknown, outside the customary range of prices, and hence the magnitude of the consumer surplus is unknowable) for guidance as to the best way to deal with the situation. Every man and woman in such a country knows from past experience what an important shortfall in grain production and a sharp rise in the price of grains means; it means that through the income effect of such a price rise, large numbers of the poor will be forced into a state of starvation, unless the shortfall is in some way offset. If the government of such a nation is a responsible government, it will be seeking ways before the advent of a production shortfall, in the midst of such a shortfall, and following it to obtain supplies of grain to offset the production shortage and thereby stabilize food prices to its people. To this end the government will require information, data, and empirical analysis with respect to the magnitudes of potential or actual production shortfalls, the numbers and locations of the persons involved, storage costs, methods of distribution, methods of financing, and outside sources of supply. But it does not require a theoretical analysis based on dubious assumptions, devoid of empirical content with regard to the possible costs and benefits to its people of a grain stabilization program, when it knows what the costs to its people of a "no-program" course of action are, and when it can obtain empirical estimates of the costs of operating such a program.

The Policy Process in the United States

The activist consumer in the United States dutifully votes for his or her governmental officers, writes to his or her congressman, votes at his or her union meeting or League of Women Voters meeting, and attends rallies on nuclear power and the high cost of living. Such a consumer may have a hazy concept of demand from some far-off course in the "Principles of Economics," but he or she will have little or no idea of how much of commodity *X* he or she will purchase if the price of commodity *X* increases by 50%, and all else remains constant, and he or she will be totally ignorant of the concept of consumer surplus and the wonderful benefits that are accruing to him or her from buying commodity *X* at the current price rather than at a price 50% higher. And God only knows what the nonactivist consumer is thinking about; it certainly will not be about his or her consumer surplus. But the activist consumer will know and the nonactivist will dimly perceive that a significant increase in grain prices will result almost immediately in an increase in the price of bread and cereal products, in an increase in the near future in dairy and poultry prices, and in an increase in the not-too-distant future in red meat prices. And even the dumbest of consumers will recognize that these increases in food product prices will, other things holding constant, result in a somewhat reduced material level of living for them. Thus, ignoring for the moment the program costs of grain price stabilization, consumers can be expected to favor a stabilization program for the grains which operates to place a ceiling over upward movements in grain prices but which does little or nothing to halt their decline.

In a comparable fashion, the individual grain producer will be well informed regarding his current cost situation, and will have a pretty good idea regarding his individual supply curve for grain over a limited range of prices. But he will be at a loss to say how much grain he would try to produce if the price of grain increased by 50%, all else holding constant, and he will be unaware of the cost and supply structures of grain producers outside his local area. Finally, he will never have heard of the concept of producer surplus. Thus, the slope and position of the supply curve for grains, outside the customary range of prices, will be a mystery to him, as it also is to economists, and the concept of producer surplus will have no meaning at all for him. But the individual grain producer will know exactly how his gross and net returns will be affected by a 10% or 20% or 30% increase, or decrease, in the price of grain, all else holding constant. And if he is an activist type he will be telling his farm organization leaders to work for, and he will be writing his congressman to elicit his support for, a program which places a floor under grain prices at or near his perceived average costs of production, and which allows grain prices to rise freely in the market above that support level.

In a society such as that in the United States in the 1970s, where the political power of consumers is emerging and grain producers continue to hang on to their power, it is reasonable to expect some form of price stabilization to take shape for the grains with both a floor and a ceiling. The current price support program for the grains and the farmer-held grain reserve are in fact a manifestation of that shared political power. Whether a grain reserve program with a greater capacity to stabilize grain prices on the upside, as well as the downside, will come into being in the 1980s is a moot question. The answer to that question will depend upon a series of developments: whether the conflicting price stabilization goals of consumers and grain producers can be further reconciled; whether the

Notes

Some Nonconformist Thoughts on Welfare Economics and Commodity Stabilization Policy

Willard W. Cochrane

The theoretical literature based upon the welfare concepts of consumer and producer surplus dealing with economic instability and commodity stabilization is wide, deep, and growing. This work will not be reviewed in this brief note, first, because it is well known to economists concerned with commodity stabilization and, second, because it recently has been surveyed by others (Burnstein; Turnovsky; Sarris and Taylor; Smith; Burmeister). As is equally known, this body of literature does not provide a conclusive argument either for or against deliberate commodity stabilization by national governments or international organizations. But it is not the purpose of this note to try to strengthen the theoretical arguments based upon welfare concepts either for or against commodity stabilization by government. It is the purpose of this note to argue that welfare analysis based upon the concepts of consumer and producer surplus has not in the past made, and will not in the future make, any recognizable contribution to the making of decisions by the United States, other developed countries, the less developed nations, or the international agencies either to initiate commodity stabilization programs or to reject them. This is true for a variety of reasons, some of which are discussed below.

Conceptual Issues

The demand curve is a powerful tool of economic analysis. It enables us to describe the quantities of a product that will be purchased at varying prices and to state how the price of a product will vary with changes in its supply. And we can derive from it such useful concepts as marginal revenue and total revenue. From it also is derived the concept of consumer surplus. I find this concept to be both slippery and of limited use, and controversy has swirled around the concept of consumer surplus since it was rediscovered and popularized among economists, at least, by Alfred Marshall around 1890 (Marshall, pp. 125–30; Currie, Murphy, and Schmitz). This is the case, first because it is not completely clear in what sense a consumer reaps an economic surplus from purchasing a given product at its current price. I, for example, cannot believe that I am the recipient of an economic surplus, if I cannot conceive of the conditions under which I would be required to purchase single units of a given product at succeedingly higher prices along my unknown demand curve for that product. The concept of consumer surplus is, for me, an illusion created by an alternative purchasing procedure which is nonoperational.

Second, consumer surplus may properly measure the change in utility to a consumer, or a group of consumers, for a change in the price of safety pins because the values involved are so small that the income effect of the price change to the consumers is negligible; hence, changes in the marginal utility of money to those consumers is negligible. But consumer surplus will not properly measure the change in utility to consumers, particularly poor consumers, for a significant change in the price of food because the income effect of such a price change becomes large relative to the incomes of those consumers; hence, the price change induces a significant change in the marginal utility of money for those consumers.

Third, it may well be the case that consumers generally would agree with Waugh that price instability is to be preferred to price stability where they know with certainty that price will fluctuate in a regular pattern such that their total expenditure for the product is reduced in a future time period over what it would be with perfect price stability. But such a formulation of the problem of product price instability might well be relegated to a footnote, as Samuelson has suggested, for the entire concept of consumer surplus. The instability problem that concerns consumers mightily is the unpredictable possibility of an increase in the price of food of such a magnitude and of such a duration that their real income position would be seriously and adversely affected.

Fourth, when the concept of producer surplus is added to the concept of consumer surplus in an analysis of product price instability, the analysis tends to become a geometric puzzle in which little boxes of uncertain content are pushed around under the assumption of regularized, predictable price fluctuations and the certainty of government compensation. This kind of puzzle-solving seems to have an appeal for some economists (Samuelson, Little), but it has little or no relevance for the uncertain world in which consumers fear the unpredictable prospect of a large upward thrust in food prices which can have devastating real income

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Beef Import Quotas." *Rev. Econ. and Statist.* 56(1974):437–49.

Rausser, G. C., and R. E. Howitt. "Stochastic Control of Environmental Externalities." *Ann. Econ. and Social Measure.* 4(1975):271–92.

Taylor, C. R., and H. Talpaz. "Approximately Optimal Carryover Levels for Wheat in the United States." *Amer. J. Agr. Econ.* 61(1979):32–40.

Zivnuska, J. A. "An Economic View of National Forest Timber Management Planning." Mimeographed. No. 6199 of the Western Timber Association, San Francisco, 1975.

Summary and Conclusions

This study has outlined the complexities of natural resource production under uncertainty. Formally, the estimation of timber stock levels and the rate of experimentation are two parts of a joint problem that, along with the determination of optimal production rates, require simultaneous solution. The LQG control model is employed as an approximately optimal solution to this problem. The LQG is seen to complement deterministic natural resource models. This complementarity allows for the inclusion of stochastic factors to analyze the varying impacts of uncertainty on policy decisions. Stochastic simulations over the planning horizon can be utilized to reveal not only the likely impact of disturbances omitted in the deterministic model, but how to minimize the cost of unexpected events. Of course, the specification of quadratic preferences implies risk aversion, which is certainly not an implausible stance for a manager of publicly owned resources.

While the strengths of LQG analysis are considerable for natural resource models, some weaknesses remain. For example, uncertainty is not modeled explicitly in the objective function, but the impact of preference uncertainty can be approximately measured by varying the objective function parameters. Varying these parameters also can be used for preposterior analysis to help policy makers define their preferences more distinctly as discussed by Rausser and Freebairn. The solution to the LQG in (8)–(10) requires that $\delta \mathbf{u}_t$ and $\delta \mathbf{x}_t$ can take on any real value, a substantial difficulty for natural resource models. Further methodological research is needed to cope with feasibility constraints in a less approximate way that is still manageable computationally.

The LQG is not the only approximation that could be used for resource management under uncertainty. The method of Taylor and Talpaz using first-order certainty equivalence is a possibility but would require iterative optimization. In problems with numerous controls, such as ours, this approach and others requiring iterative methods are not practical. Additionally, it is important that the approximating method used should incorporate an observer and state estimation capability that can be readily utilized.

The application of the LQG model to the harvest scheduling problem of a national forest illustrates why policy makers are justified in not adhering strictly to plans generated by deterministic models. The simulations demonstrate the impact of uncertainty on production levels and give the relative costs of various sources of uncertainty. Thus the scheduling of production and the allocation of research funds or, indeed, the allocation of capital between information collection and production, can be approached more rationally. Since the problems of research and production are being jointly solved for most empirical problems, it is not unreasonable that plans and policies from deterministic models are not more widely applied.

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References

Aoki, M. *Optimization of Stochastic Systems*. New York: Academic Press, 1967.

Athans, M. "The Discrete Time Linear-Quadratic-Gaussian Stochastic Control Problem." *Ann. Soc. and Econ. Measure.* 1(1972):449–91.

Burt, O. R., and R. A. Cummings. "Production and Investment in Natural Resource Industries." *Amer. Econ. Rev.* 60(1970):576–90.

Chow, G. C. *Analysis and Control of Dynamic Economic Systems*. New York: John Wiley & Sons, 1975.

Clawson, M. *Forests for Whom and for What?* Baltimore, Md.: Johns Hopkins University Press, 1975.

Dixon, B. L., and R. E. Howitt. "Uncertainty and the Intertemporal Forest Management of Natural Resources: An Empirical Application to the Stanislaus National Forest." Giannini Foundation Monograph No. 38, University of California, Berkeley, 1979.

Joseph, P. D., and J. T. Tou. "On Linear Control Theory." *AIEE Transactions* (Applications and Industry) 89(1961):193–96.

Kim, H. K., L. M. Goreaux, and D. A. Kendrick. "Feedback Control Risk for Cocoa Market Stabilization." *Quantitative Models of Commodity Markets*, ed. W. C. Labys. Cambridge, Mass.: Ballinger Publishing Co., 1975.

Navon, Daniel I. "Timber RAM . . . A Long Range Planning Method for Commercial Timber Lands Under Multiple-Use Management." Washington, D.C.: USDA Forest Serv. Res. Pap. PSW-70/1971.

Norman, A. L. "First Order Dual Control." *Ann. Econ. and Soc. Measure.* 5(1976):311–21.

Rausser, G. C. "Active Learning, Control Theory, and Agricultural Policy." *Amer. J. Agr. Econ.* 60 (1978):476–90.

Rausser, G. C., and J. W. Freebairn. "Estimation of Policy Preference Functions: An Application of U.S.

Table 3. Decomposition of the Objective Function for Simulations One and Four

Period (t)	Objective Function [$E(J_t)$]	Current Deviation Cost ($\delta \mathbf{x}'_{t\|t}\mathbf{H}_t\mathbf{x}_{t\|t}$)	Current Stock Estimate Uncertainty ($tr.\mathbf{H}_t\mathbf{P}_{t\|t}$)	Cost of Growth Dynamics Uncertainty ($\Sigma tr.\mathbf{H}_{t+1}\Omega_t$)	Cost of Future Uncertainty in Estimating Stocks ($\Sigma tr.\mathbf{A}'_t\mathbf{H}_{t+1}\mathbf{B}_t\mathbf{G}_t\mathbf{P}_{t\|t}$)
			Simulation One		
0	.117E + 02	.267E + 01	.132E + 01	.757E + 01	.106E + 00
1	.124E + 02	.445E + 01	.556E + 00	.732E + 01	.922E − 01
2	.140E + 02	.646E + 01	.354E + 00	.710E + 01	.899E − 01
3	.119E + 02	.461E + 01	.266E + 00	.690E + 01	.872E − 01
4	.121E + 02	.517E + 01	.179E + 00	.675E + 01	.807E − 01
			Simulation Four		
0	.169E + 05	.107E + 03	.994E + 04	.648E + 04	.384E + 03
1	.498E + 04	.275E + 03	.222E + 04	.239E + 04	.952E + 02
2	.269E + 04	.953E + 03	.765E + 03	.942E + 03	.319E + 02
3	.794E + 03	.102E + 03	.283E + 03	.399E + 03	.103E + 02
4	.386E + 03	.837E + 02	.109E + 03	.189E + 03	.419E + 01

(or cardinal) costs of uncertainty can invest in improved passive information to reduce these costs. It can be seen easily from table 3 that for this problem, the costs of uncertainty exceed the costs of target deviation influenced by direct policy actions.

Table 3 decomposes the costs for $S1$ on a period-by-period basis for the first five periods. For the initial period, the future cost of stock evolution uncertainty, $\Sigma tr.\mathbf{H}_{t+1}\Omega_t$, is 65% of the expected total costs. The importance of this source of uncertainty relative to the costs of imprecise timber volume estimation in the successive time periods, $\Sigma tr.\mathbf{A}'_t\mathbf{H}_{t+1}\mathbf{B}_t\mathbf{G}_t\mathbf{P}_{t|t}$ and $tr.\mathbf{H}_t\mathbf{P}_{t|t}$, is evident in table 3. The total cost of future additive uncertainty about the dynamics exceeds the cost of future stock estimation uncertainty in every period as shown by comparing the fourth column in table 3 with the fifth column. Thus, for preferences that emphasize the maintenance of targeted harvest levels, more is gained by lowering the additive uncertainty in the dynamic growth equations, Ω_t, than observation uncertainty. Furthermore, lessening uncertainty about the dynamics also serves to lessen the covariance of the state vector estimate due to the recursive nature of the Kalman estimator. In effect, the precision of state variable predictions based on prior sample data is increased so that *ceteris paribus*, the precision of all future state vector estimates is increased.

When nonstumpage loss values are included in the preferences, the largest percentage share of uncertainty costs shifts to the imprecision of current stock level estimates. In the initial period, the cost of current uncertainty in the estimate of the stock levels, $tr.\mathbf{H}_0\mathbf{P}_{0|0}$, is 59% of the expected total costs as indicated in table 3. This result follows naturally when nonstumpage benefits are derived from the current stocks. It can be further observed in table 3 that the cost of dynamics' uncertainty, $\Sigma tr.\mathbf{H}_{t+1}\Omega_t$, is greater than the cost of future stock estimates, $\Sigma tr.\mathbf{A}'_t\mathbf{B}_t\mathbf{H}_{t+1}\mathbf{G}_t\mathbf{P}_{t|t}$, so that once again the cost of future dynamics' uncertainty is greater than the cost of estimating future stock levels. The implication is that the future growth estimation uncertainty, Ω_t, is of greater cost than future observer uncertainty, θ_t.

Given the large proportion of costs accounted for by current uncertainty in the state estimate for $S4$, it would be prudent to attempt lessening of the current stock estimate's variance. In the LQG problem, the initial state covariance, $P_{0|0}$, is a prespecified parameter, a realistic assumption because the sampling of forest stocks cannot be undertaken at a moment's notice. Thus the decision makers should reexamine existing data and estimation methods to see if the current stock levels could be estimated with greater precision.

A strong case can be made that the growth dynamics error should be lessened relative to observer imprecision, irrespective of which of the preferences in $S1$–$S5$ is selected to determine management actions. However, the rate of return to expenditures on uncertainty reducing research must also be considered in determining the most efficient allocation of resources for passive information acquisition.

Table 2. Mean Norms for the Control Vectors for Five Periods for the Five Different Preferences

Preference Period	S1	S2	S3	S4	S5
1	.082	2.398	3.786	8.037	11.351
	(.007)	(.280)	(.442)	(.936)	(1.314)
2	.177	3.229	4.911	9.182	11.690
	(.014)	(.336)	(.492)	(.810)	(1.009)
3	.413	2.533	3.648	5.839	7.288
	(.032)	(.215)	(.302)	(.463)	(.579)
4	.598	2.864	3.904	5.562	7.317
	(.036)	(.196)	(.259)	(.408)	(.457)
5	1.107	2.946	3.653	4.467	5.332
	(.077)	(.214)	(.268)	(.390)	(.445)

Note: The norms are in millions of cubic feet and the standard error of each mean is given in parentheses below each sample mean.

effort being exerted. It can be readily observed that in comparison with all of the norms for $S1$, the other preference structures result in much more control action. Thus it is clear that the preference structure results in actions that strongly favor taking nearly all the scheduled harvests in each period and letting stocks vary from their targets. When $\mathbf{Q}_t$ is increased parametrically, the control trajectories first change substantially even for seemingly small values of $\mathbf{Q}_t$. In periods one through five the mean norms for $S2$ are at least two-and-a-half times as large as those in $S1$. For preference weightings $S3$, $S4$, and $S5$ the corresponding norms are larger than those in $S2$, but the rate of increase decreases rapidly as a function of the increases in $\mathbf{Q}_t$. It is clear that as the nonzero elements of $\mathbf{Q}_t$ increase, the harvest levels are increasingly set to insure that the targeted stocks and their associated benefits will be available for future periods. Observe that the marginal change in the control norms is relatively small once the nonzero elements of $\mathbf{Q}_t$ are greater than one.

The basic patterns of the simulated trajectories over varying preference weights $S1$–$S5$ can be summarized as follows: due to the uncertainty in the model represented by the additive error terms $\mathbf{e}_t$ and $\mathbf{v}_t$, either control deviations or stock deviations must be tolerated. For this particular model and for most forestry models, the greatest sensitivity of controls is when the nonstumpage benefits of the timber stocks per period are substantially less than the benefits generated by the harvest of a unit of timber in a given period. Timber growth is slight over a ten-year period for most stands, so that removal of part of a timber resource has substantial implications for numerous future decades. Thus uncertainty about the management preferences is most crucial for the level of control actions when the nonstumpage benefits of the timber stock per period are quite modest relative to the stock's harvest value.

Cost of Additive Errors to Dynamics and Stock Observation Systems

The simulated results from the prior sections emphasize the importance of knowing which preference structure is to be implemented. In this section, the cost of uncertainty about the physical system is considered from two directions. First, which of the sources of uncertainty about the physical resources tend to be most costly for a given preference weighting and, second, how the relative costs of uncertainty vary across the set of preferences represented in $S1$–$S5$.

In analyzing the costs of uncertainty, the decomposition of the expected cost as given in (11) is utilized extensively. The impacts of uncertainty in $S1$–$S5$ can be dichotomized conveniently. The costs of a given source of uncertainty under the various preferences in $S2$–$S5$ are approximately proportional to the loss value of nonstumpage benefits. Thus, the analysis of the costs of uncertainty can be limited to a comparison of the costs between the stumpage-oriented objective function, $S1$, and the objective function $S4$, which has equal loss values for both stumpage and stock deviations.

Because the preferences $S1$–$S5$ use an arbitrary loss unit and the costs are invariant under a linear transformation, only ordinal and percentage comparisons can be made. Nevertheless, these results are useful to the resource manager concerned with allocating an operating budget between competing needs. What is of primary importance for optimal resource management is that the relative costs of uncertainty are known. Because the control actions are optimal, the costs of direct policy action in column two of table 3 cannot be reduced. However, a manager who knows the ordinal

stochastic simulations is a measure of the relative responsiveness of the controls under the preferences $S1$–$S5$. An alternative measure of responsiveness would be the mean absolute deviation of the controls from their target values.

watershed management, wildlife conservation) as summarized in Clawson, the set of objective functions is structured to represent this diversity. Each deviation from a scheduled harvest is given a weight of unity and the weights for each deviation from a target volume for five different preference sets are shown in table 1. The terminal volume deviation cost is simply the sum of squared volume deviations in each class for all of the simulations. The costs in each period are discounted at 7% per year.[3]

Control Model Solution Procedure

The optimal filter estimates, covariances, and optimal controls are calculated using a program written by the authors. The solution procedures for the linear Kalman filter are closely analogous to the LQG control solution, so only the latter will be outlined.

Careful perusal of equations (10), (9), (8), and (5) shows the basis of the analytic solution procedure. In equation (10), the transversality condition defines the terminal costate matrix, $\mathbf{H}_T$ as equal to $\mathbf{Q}_T$. This allows solution of last-period gain matrix, $\mathbf{G}_{T-1}$ from equation (9). Substitution of $\mathbf{G}_{T-1}$ into equation (10) enables the costate matrix $\mathbf{H}_{T-1}$ in the $T-1$th period to be calculated. Thus the costate and gain matrices for each time period are solved in a backwards recursive manner and stored in the computer memory. Using equation (8), $\delta\mathbf{x}_{0|0}$ and $\mathbf{G}_0$, the optimal initial control $\delta\mathbf{u}_0$ is calculated and implemented. At the beginning of the next period $\delta\mathbf{x}_{1|1}$ is estimated using the Kalman filter and the whole process is repeated.

Table 1. Values of the Undiscounted, Nonzero Elements of the Objective Function Weighting Matrices

Preference Set	$\mathbf{R}_t$	$\mathbf{Q}_t$
*S*1	1.0	0.0
*S*2	1.0	0.1
*S*3	1.0	0.2
*S*4	1.0	1.0
*S*5	1.0	4.0

In the runs analyzed in this study, a random number generator is used to simulate $\mathbf{e}_t$ and $\mathbf{v}_t$, the random error terms. The dominant sources of computing costs lie in the storage of the $\mathbf{G}_t$ and $\mathbf{H}_t$ matrices in each time period and the inversion of the matrix $[\mathbf{R}_t + \mathbf{B}'_t\mathbf{H}_{t+1}\mathbf{B}_t]$, which has the dimensions of the vector of control variables. Using this approach, optimal unconstrained controls for systems exceeding twenty state variables and twenty controls can be solved at moderate cost.

Analysis of Simulations

The results of stochastic simulations are analyzed in this section to demonstrate the usefulness of the LQG model for policy evaluation under uncertainty. The effects of differing objective function weights in response to estimated deviations and the impact and costs of various sources of uncertainty are analyzed.

The Effect of Changing Preferences on Control Response

Due to the quadratic form of the objective function, certain characteristics of the controls are predictable. As discussed in Athans, the relative weight of $\mathbf{Q}_t$ to $\mathbf{R}_t$ indicates how responsive the controls are to estimated deviations in the state vector. Referring to the definition of the control matrix $\mathbf{G}_t$ in (9), it is apparent that with $\mathbf{R}_t$ fixed, control response increases with increases in the size of the elements of the $\mathbf{Q}_t$. However, the rate of increase in control response generally will decrease with further increases in the $\mathbf{Q}_t$. The important question from a management point of view is for what values of $\mathbf{Q}_t$ will small variations in the objective function weights have the greatest impact on the control levels?

The answer to this question is revealed in table 2, which gives the means of the norms of the control vectors over thirty stochastic simulations for each of the five objective function specifications.[4] The norm (Euclidean length) of a vector is used as a measure of the control effort.[5] The larger a norm is, the more control

[3] A potentially disturbing aspect of the quadratic preferences is that the $\mathbf{x}^*_t$ and $\mathbf{u}^*_t$ define bliss points. However, greater timber densities do not necessarily have positive marginal benefits for nonstumpage flows. Thus the bliss point characteristics of quadratic preferences are not a substantial detriment in this application.

[4] Despite the construction of $\mathbf{B}_t$ designed to avoid infeasible controls, about 6% of the controls were infeasible. These were set to the nearest feasible value, similar to the method in Kim, Goreaux, and Kendrick.

[5] Chow states that $\mathbf{G}'_i\mathbf{G}_i > \mathbf{G}'_j\mathbf{G}_j$ by a positive semidefinite matrix where i and j denote different G's in (9) indicates more policy response to a given, estimated deviation in the state vector. Hence, comparing the mean norm of the control vector over

cate how research efforts might be allocated between increasing knowledge of production and growth processes or sampling of resource stocks. In the LQG formulation, the optimal observation intensity problem is not explicitly solved. As discussed in Rausser and Howitt, computation of the optimal sampling intensity usually must be computed numerically for even algebraically simple problems.

Description of Empirical Model

This section briefly describes harvest scheduling on the Stanislaus National Forest and then transforms the problem into a linear-quadratic-Gaussian model. Our discussion is descriptive because the details of parameter estimation are lengthy and given fully in Dixon and Howitt. The model used to derive the target trajectory of state and control variables is discussed first, and then the quadratic preferences and linearized dynamics are described.

The Underlying Problem

The current harvest-scheduling policy for national forests as given in the National Forest Management Act of 1976 (Public Law 94-588) is to ". . . limit the sale of timber from each national forest to a quantity equal to or less than a quantity which can be removed from such forest annually in perpetuity on a sustained-yield basis . . ." (Sec. 11). The Act further provides that the Secretary of Agriculture may allow departures from the projected long-term average sale quantity to meet overall multiple-use objectives. The de facto harvest-scheduling policy utilized by the United States Forest Service, as discussed in Zivnuska, basically is maximizing the first decade harvest subject to the constraint of even-flow and nondeclining yield.

The target trajectory used in this study is derived from a linear programming model developed by Navon called the Timber Resources Allocation Method (Timber RAM) which is used by the Forest Service on the Stanislaus. Only seven classes of the mixed conifer timber type, which is 49% of the area in the forest suitable for timber production, are modeled for the first ten decades of the thirty-eight-decade deterministic trajectory to limit computing costs.

The Linearized Growth and Observation Models

The dynamics of timber growth in the Stanislaus are based on stand age and the level of basal area per acre. Basal area is the area of any given acre occupied by standing timber where the area occupied by a tree is measured at a height of four and one-half feet. Timber volume is computed as a function of basal area and age in each period where each period is a decade. The components of $\delta \mathbf{x}_t$ are the levels of volume and basal area for the various age classes. The A_t, which are time varying, give the linear approximations of volume and basal area evolution.

The control matrices, $\mathbf{B}_t$, measure the impact of thinnings and regeneration harvests, the only control actions considered in Timber RAM for the timber stocks. To avoid numerous infeasible control levels, the $\mathbf{B}_t$ are constructed so that only the controls with positive target levels are allowed to vary in the computed solutions.[1] In the observation system on the Stanislaus, precision on basal area observations is set initially with the standard error equal to 5% of the target level of basal area being observed. The level of observation precision is always a managerial input to an LQG model. The precision can be varied to determine approximately the most efficient level of observation precision. The remaining variances and covariances in the LQG model are derived from the regression results used to estimate the growth dynamics.[2]

Specification of the Quadratic Objective Function

The Multiple Use Sustained Yield Act does not define a financial criterion for National Forest management; therefore, we specify a set of alternative objective function weights for analysis. Because the current debate on national forest utilization is largely between the intensity of stumpage (the term stumpage is used here to refer to the volume of harvest) versus nonstumpage uses (recreation,

[1] This construction also avoids the problem of scheduling many relatively small harvests in many of the classes in each time period.

[2] The levels of the variances and covariances of the additive error terms, $\mathbf{e}_t$ and $\mathbf{v}_t$, are a function of the levels of the timber stocks and, hence, the controls. Thus, the separation principle for state vector estimation no longer holds. An exact solution to this problem would require impractical numerical methods. Hence, we assume that the separation principle holds and the covariances are fixed.

To solve the more general problems not fitting the specification above, the tracking approach of LQG method can be employed. The tracking approach utilizes a three-step procedure to design and solve an approximate model of the underlying problem. In the first step the objective function (preferences), resource dynamics, and observation process of the underlying problem are specified in their most accurate algebraic (usually nonlinear) form, but are assumed to be deterministic. This deterministic problem is optimized and the resulting trajectory of state and control variables then constitutes the target trajectory. The optimizing philosophy is to keep the actual evolution of the system "close" to these targets.

At step two, the resource dynamics and observer are linearized about the target values of the state and control variables via Taylor's Theorem. A quadratic objective function is specified to measure the loss of deviating from the target values. Minimizing the expected loss from deviations subject to the linearized resource dynamics and observer constitutes a linear-quadratic control problem when additive Gaussian error terms are appended to the linearized dynamics and observer. The third step is the real time control of the evolving system. Samples are taken to estimate the current level of the state variables, and then the control actions for the current period are computed as a function of the estimated states. This estimation-control cycle is repeated in every period.

It is immediately apparent that the tracking model complements deterministic control models of resource production because their solution provides the target levels needed in step one of the LQG method. Derivation of the solution to linear-quadratic-Gaussian control models is given in Aoki, so it is reviewed tersely. Assuming that a set of target values $\mathbf{x}^*_t$, $\mathbf{u}^*_t$, and $\mathbf{y}^*_t$ are available from a deterministic model, the LQG is stated in terms of control, state, and observation deviations, where

$$\delta\mathbf{x}_t = (\mathbf{x}^*_t - \mathbf{x}_t) \qquad \delta\mathbf{u}_t = (\mathbf{u}^*_t - \mathbf{u}_t) \qquad \delta\mathbf{y}_t = (\mathbf{y}^*_t - \mathbf{y}_t).$$

The resource dynamics and observer relationships are linearized around $\mathbf{x}^*_t$ and $\mathbf{u}^*_t$, as

$$(5) \qquad \delta\mathbf{x}_{t+1} = \mathbf{A}_t\delta\mathbf{x}_t + \mathbf{B}_t\delta\mathbf{u}_t + \mathbf{e}_t,$$

$$(6) \qquad \delta\mathbf{y}_t = \mathbf{C}_t\delta\mathbf{x}_t + \mathbf{v}_t,$$

where $\delta\mathbf{x}_t$ is nx1, $\mathbf{A}_t$ nxn, $\delta\mathbf{u}_t$ mx1, $\mathbf{B}_t$ nxm, $\delta\mathbf{y}_t$ rx1, and $\mathbf{C}_t$ is rxn. Finally, $\mathbf{e}_t$ and $\mathbf{v}_t$ are nx1 vectors of Gaussian errors with serially uncorrelated covariances, Ω_t and θ_t, respectively; and $E(\mathbf{v}_i\mathbf{e}_j) = 0$ for all i, j. The objective of minimizing the expected cost of deviations is written as

$$(7) \qquad E(J_0) = E\sum_{t=0}^{T-1}(\delta\mathbf{x}'_t\mathbf{Q}_t\delta\mathbf{x}_t + \delta\mathbf{u}'_t\mathbf{R}_t\delta\mathbf{u}_t) + \delta\mathbf{x}_T\mathbf{Q}_T\delta\mathbf{x}_T.$$

Under this LQG specification, the joint problems of optimal control derivation and state estimation are solved independently (Joseph and Tou). Defining the conditional estimate of $\delta\mathbf{x}_i$, given all the samples and controls through j as $\delta\mathbf{x}_{i|j}$, the optimal controls are

$$(8) \qquad \delta\mathbf{u}_t = \mathbf{G}_t\delta\mathbf{x}_{t|t} \quad t = 0, \ldots, T-1, \text{ where}$$

$$(9) \qquad \mathbf{G}_t = -[\mathbf{R}_t + \mathbf{B}'_t\mathbf{H}_{t+1}\mathbf{B}_t]^{-1}\mathbf{B}'_t\mathbf{H}_{t+1}\mathbf{A}_t \quad t = 0, \ldots, T-1, \text{ and}$$

$$(10) \qquad \mathbf{H}_t = \mathbf{Q}_t + \mathbf{A}'_t\mathbf{H}_{t+1}\mathbf{A}_t + \mathbf{A}'_t\mathbf{H}_{t+1}\mathbf{B}_t\mathbf{G}_t, \quad t = 0, \ldots, T-1,$$

with $\mathbf{H}_T = \mathbf{Q}_T$. Estimates of $\delta\mathbf{x}_t$, $\delta\mathbf{x}_{t|t}$, which are optimal with respect to minimizing costs in (7), are generated by the Kalman filter. The covariance of $\delta\mathbf{x}_{i|j}$ is $\mathbf{P}_{i|j}$, and the recursive equations that generate the estimate and its covariance are given by Athans.

The expected loss for any period t is:

$$(11) \qquad E(J_t) = \delta\mathbf{x}'_{t|t}\mathbf{H}_t\delta\mathbf{x}_{t|t} + tr.\mathbf{H}_t\mathbf{P}_{t|t} + \sum_{i=t}^{T-1} tr.\mathbf{H}_{i+1}\Omega_i + \sum_{i=t}^{T-1} tr.\mathbf{A}'_i\mathbf{H}_{i+1}\mathbf{B}_i\mathbf{G}_i\mathbf{P}_{i|i}.$$

Only the first term in (11) is a function of the estimated deviations, a similar expression as would be obtained from a deterministic model. The last three terms of (11) are the costs of various sources of uncertainty. The second and fourth terms represent the cost of current and future uncertainty from not being able to observe the resource stock perfectly. The third term yields the present cost of future uncertainty about resource evolution through time. This uncertainty arises from the inherent uncertainty in (2) and the approximation error induced by linearization.

The three uncertainty cost terms provide the policy maker with the decision relevant value of better information. These costs indi-

strate some of the advantages of its use for decision making and problem analysis over strictly deterministic methods. Limiting aspects of the LQG approach also are discussed.

In the first section, the changes in the management problem induced by relaxing the certainty assumption of deterministic models are considered. This discussion motivates the use of approximate stochastic models. The second section discusses the theory and empirical application of the LQG technique. In the concluding sections, the LQG approach is applied to harvest scheduling on a national forest. The first of these sections briefly describes the resource model and management objectives, and in the final section the results and policy relevant aspects of 150 stochastic simulations are analyzed.

Natural Resource Production under Certainty and Uncertainty

To frame a generalized, deterministic, resource production problem, it is assumed that the owner's objective function can be written as

$$(1) \qquad \text{Max} \sum_{t=0}^{T-1} B_t(\mathbf{x}_t,\mathbf{u}_t) + B_T(\mathbf{x}_T),$$

where $\mathbf{x}_t$ is a vector of state variables representing resource and capital stock levels and T denotes the terminal period. The control vector, $\mathbf{u}_t$, gives the rates of production and investment; time discounting is assumed implicit in the form of B_t. The resource dynamics are modeled as

$$(2) \qquad \mathbf{x}_{t+1} = f_t(\mathbf{x}_t,\mathbf{u}_t),\ \mathbf{x}_0 = \mathbf{x}(0).$$

It is assumed that the state and control vectors are confined to a prespecified feasibility region L:

$$(3) \qquad \mathbf{x}_t,\mathbf{u}_t \in L.$$

As shown in Burt and Cummings, the necessary conditions that maximize (1) subject to (2) and (3) yield the familiar rule that current production should be increased until the marginal benefit of current production equals the marginal cost of future profits foregone by producing today, i.e., user costs.

It is assumed in (1)–(3) that all of the stock levels, $\mathbf{x}_t$, are observed perfectly in each time period. This assumption is a major weakness in problems of resource production when the stock of available resource, or its effective productive capacity, is uncertain. The stock of usable timber within any given geographical region is uncertain until harvested. This same problem is present in various ways in fish, water, mineral, and environmental resources. It follows that the uncertainty about levels of productive resource stocks is central to resource management plans. To represent the reality of inexact knowledge of resource stocks, we posit an observer or measurement relationship

$$(4) \qquad \mathbf{y}_t = g_t(\mathbf{x}_t),$$

where the vector $\mathbf{y}_t$ is a signal or observation generated as a function of the state vector and a random component.

Two additional sources of uncertainty complicate the empirical problem of resource management. The value of goods and services derived from resource stocks is usually uncertain and the physical evolution of resource stocks subject to control actions is not precisely known. The problem of valuing resource worth or prices is particularly vexing for publicly owned resources that are to be managed to maximize vaguely defined social welfare.

In coping with these three sources of uncertainty, the manager must determine production rates and rates of information acquisition. Information gathering can take the form of purchase of information, active learning, and setting of the observation or sampling precision. Even for very simplified problems, the optimal solution requires simultaneous determination of production and information gathering. Such solutions usually are numerically burdensome. For almost any empirical problem, theoretical elegance and exact specification must be exchanged for a workable model.

LQG Methodology

The LQG control method, as summarized and analyzed in Athans, solves two different stochastic control problem specifications known as basic trajectory and tracking, respectively. If (*a*) the resource dynamics (2) and observer (4) are linear with additive, Gaussian (normally) distributed errors, (*b*) the objective function is quadratic and known, and (*c*) the state and control variables can take on any real value, the optimal controls can be derived analytically.

Resource Production under Uncertainty: A Stochastic Control Approach to Timber Harvest Scheduling

Bruce L. Dixon and Richard E. Howitt

Most empirical natural resource management problems are intertemporal optimization problems under uncertainty. The Linear-Quadratic-Gaussian (LQG) method derives an approximate stochastic solution to such problems. The error in modeling resource dynamics and error in observing resource stocks are incorporated explicitly into the LQG problem solution. The LQG is outlined briefly and applied to the harvest-scheduling problem on the Stanislaus National Forest. The importance of knowing management preferences precisely is shown by stochastic simulations. In particular, harvest levels and the cost of a given source of uncertainty are shown to be quite sensitive to the objective function specification.

Key words: resource management, stochastic optimal control, timber harvest scheduling.

The problem of efficient production from natural resources is conventionally approached by constructing a deterministic model of management objectives and resource dynamics from which the optimal intertemporal production schedule is derived. The literature abounds with theoretical resource models, but few have been applied and used for public policy. Given the current interest and concern with optimal resource use, why are the deterministic models not embraced by policy makers? One answer that this paper advances is that due to its specification, the deterministic resource model essentially ignores two of the critical areas of public resource policy: response to parameter uncertainty and investment in information to lessen uncertainty. Because investment in information can be justified only on the basis of improved future decision making, the information problem can be viewed as the dual to the primal problem of determining the intertemporal production rates under uncertainty.

Experiments often are conducted separately from the actual production process, and then the resulting information can be incorporated into the production problem. An example of this is the use of experimental plots to generate knowledge to be applied to managing an entire resource stock, in this case a forest. Additionally, it may be possible to purchase information. For either of these methods of essentially passive information accumulation the decision maker must determine the cost of the current and future levels of uncertainty. As discussed by Rausser, the theoretically optimal solution to the control-parameter estimation problem includes the use of active learning strategies. However, the computational burden of active learning solutions can be excessive even for modestly sized problems and the performance of an approximate active learning solution does not necessarily surpass that of passive strategies (Norman).

Recent advances in optimal control methods have yielded solution procedures that allow for incorporation of significant stochastic components of the resource management problem. In this paper one of these methods, the Linear-Quadratic Gaussian (LQG) control model, is used for the problem of harvest scheduling on a national forest. Our purpose is to state the stochastic resource production problem for the LQG specification and demon-

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source but that if any mining of the resource is contemplated, that taxation provides for the greatest social value of the groundwater being achieved.

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References

Baumol, W. J. "On Taxation and the Control of Externalities." *Amer. Econ. Rev.* 62(1972):307–22.

Bear, J., and O. Levin. "Optimal Utilization of an Aquifer as an Element of Water Resources System." *Selected Works in Operations Research and Hydraulics, Published in Memory of Oded Levin.* Haifa, Israel: Technion, 1970.

Bredehoeft, J. D., and R. A. Young. "The Temporal Allocation of Groundwater—A Simulation Approach." *Water Resour. Res.* 6(1970):3–21.

Buras, N. "Conjunctive Operations of Dams and Aquifers." *J. Hydraulics* 89(1963):107–29.

Burt, O. R. "Economic Control of Groundwater Reserves." *J. Farm Econ.* 48(1966):632–47.

———. "Groundwater Management and Surface Water Development for Irrigation." Paper presented at joint meetings of the Operations Research Society of America and Institute of Management Sciences, San Juan, Puerto Rico, 17 Oct. 1974.

———. "Groundwater Management under Quadratic Criterion Functions." *Water Resour. Res.* 3(1967a):673–82.

———. "Optimal Resource Use over Time with an Application to Groundwater." *Manage. Sci.* 11(1964):80–93.

———. "Temporal Allocation of Groundwater." *Water Resour. Res.* 3(1967b):45–56.

California Department of Water Resources. *California Groundwater.* Bull. No. 118, 1975.

Gisser, M. "Linear Programming Models for Estimating the Agricultural Demand Function for Imported Water in the Pecos River Basin." *Water Resour. Res.* 6(1970):1025–32.

Gisser, M., and A. Mercado. "Economic Aspects of Groundwater Resources and Replacement Flows in Semi-Arid and Agricultural Areas." *Amer. J. Agr. Econ.* 55(1973):461–6.

———. "Integration of the Agricultural Demand Function For Water and the Hydrologic Model for the Pecos Basin." *Water Resour. Res.* 8(1972):1373–84.

Kelso, M. M. "The Stock Resource Value of Water." *J. Farm Econ.* 43(1961):1112–29.

Milliman, J. W. "Commonality, the Price System, and the Use of Water Supplies." *S. Econ. J.* 22(1956):426–37.

Mishan, E. J. *Cost-Benefit Analysis.* New York: Praeger Publishers, 1976.

Moore, C. V., and T. R. Hedges. "A Method for Estimating the Demand for Irrigation Water." *Agr. Econ. Res.* 15(1963):131–5.

Noel, J. E. "Dynamic Water Management: An Optimal Control Approach." Ph.D. Thesis, University of California, Davis, 1979.

Pigou, A. C. *The Economics of Welfare.* London: Macmillan & Co., 1932.

Pontryagin, L. S., V. S. Bollyonskii, R. V. Gamkreligze, and E. F. Michcheuko. *The Mathematical Theory of Optimal Processes.* New York: John Wiley & Sons, 1962.

Renshaw, E. F. "The Management of Groundwater Reservoirs." *J. Farm Econ.* 45(1963):285–95.

Samuelson, P. A. "Spatial Price Equilibrium and Linear Programming." *Amer. Econ. Rev.* 42(1952):283–303.

Savage, M., and O. Helweg. *Documentation for a City Water Demand Simulation Model.* Dep. Civil Engin., University of California, Davis. 1978.

Scott, A. T. "The Theory of the Mine under Conditions of Certainty." *Extractive Resources and Taxation,* ed. Mason Gaffney. University of Wisconsin Press, 1967.

Scott, V. H., and J. C. Scalmanini. *Investigation of Groundwater Resources: Yolo County, California.* Dep. Water Sci. and Engin. Pap. No. 2006, University of California, Davis, Sep. 1975.

Takayama, T., and G. G. Judge. "An Interregional Price Equilibrium Model of the Agricultural Sector." *J. Farm Econ.* 46(1964):349–65.

Table 7. Optimal Tax Rate Schedule for the Yolo County Groundwater Basins (1977–2000, $0.045/Kwh.)

Groundwater Basin	1977	1980	1985	1990	1995	2000
	Tax ($/acre-feet)					
Cache Creek	6.01	4.84	3.38	2.37	1.62	1.03
Upper Cache-Putah	8.73	7.12	5.04	3.51	2.34	1.38
Plainfield Ridge	240.39	129.32	47.77	16.55	4.26	0.17
Lower Cache-Putah	10.62	8.42	5.62	3.63	2.13	1.12
Colusa	7.66	6.35	4.60	3.30	2.33	1.55
East Yolo	2.66	2.19	1.57	1.12	0.78	0.51

of values, depending on several factors: (*a*) the physical parameters of the individual basins; (*b*) the costs associated with pumping a unit of groundwater; and (*c*) the economic demands for current use (both for agriculture and urban use).

Finally, the tax rate declines over time under constant energy costs, a result to be expected since over time the stock values (user costs) decline. This reduces the disparity between the restricted pumping situation and the socially optimal allocation, and the tax rate correspondingly declines.

From an analytical viewpoint the two methods of dealing with commonality of water use offer very different lines of attack. Quota setting in effect imposes a tighter constraint on the resource than does taxation. Quota setting transfers the decision making from the private user to a central agency. Taxation allows greater flexibility because the decision on pumpage is left to the individual user. The tax simply becomes another component of the pumper's cost function and is taken into consideration when deciding how much water should be used in any time period. Baumol demonstrates that where an externality (technical) exists that taxes upon the generator of the externality are all that is required to produce an efficient allocation. Baumol argues that even if the level of taxation needs to be adjusted in a tâtonnement process to achieve the desired result, it is still the best way to correct the divergence between social and private cost.

Concluding Remarks

This paper has proposed a control model framework for determining the optimal spatial and temporal allocation of water in a complex hydrologic and economic setting. The advantage of this framework over past work done in the area of water resource allocation is the ability of the model to handle a large degree of disaggregation and to provide valuable economic and hydrologic information about the physical system with respect to its common pool nature. Thus, this paper demonstrates the usefulness of a framework that can take the interaction of several groundwater basins into consideration as the socially optimum allocations are determined. Two broad policy implications can be drawn from the results.

First, the areal size of a water resource-planning unit must be chosen with care. The results presented in this paper illustrate quite dramatically that the six basins making up the Yolo County aquifer react differently to alternative economic and hydrologic parameters. In terms of policy, this means that designation of groundwater planning units should be based on economic and hydrologic parameters and not on political or geographical boundaries. The degree of hydrologic interdependence between different basins in the same aquifer, or between aquifers, is the key factor in determining any planning unit. These interdependencies are directly related to the common pool problem associated with groundwater use. If the interdependencies are not accounted for in the allocation decision, there will be a large reduction in the social value of the groundwater resource.

The second policy implication relates to the economic impacts associated with policy alternatives for moving current groundwater allocations to a more socially preferred set. Although taxation and pro-rata allocations have been suggested a number of times in the literature as institutional instruments to achieve a more socially optimal allocation of resources, the current framework has shown the change in social value of the resource that can be expected upon their implementation. The results indicate that both instruments will increase the social value of the groundwater re-

Table 6. Yearly and Total Present Value of the Water Resource under Socially Efficient and Private Decision Allocations (1977–2005, $0.045/Kwh.)

Value Measure	1977	1980	1985	1990	1995	2000	2005	Total[a]
	($ thousand)							
Social	22,112	16,860	12,820	9,230	6,150	4,410	3,120	294,240
Private	18,068	14,694	10,485	7,174	5,103	3,612	2,565	241,322
Difference	4,044	2,166	2,335	2,056	1,047	798	555	52,918

[a] Represents total value of the water resource over the entire planning horizon.

cial optimum and the private optimum value of the water resource, much larger than the difference between the social optimum and the quota solution described above. These differences, however, are not directly comparable because they measure different things. The difference between the quota and the socially optimum value represents the returns foregone if the amount of groundwater usage is limited to a long-run mean recharge quota. The unrestricted pumping value is a measure of the external cost imposed on all water users by the failure of individual pumpers to take into account the total social costs of individual pumping. The total difference between the social optimum and the private solution is $52,918,000 over the thirty-year-planning horizon. In comparing the unrestricted solution to the quota policy solution, it must be concluded that neither policy is efficient. However, the quota policy appears better to approximate the social optimum than does the unrestricted pumping policy. Thus, a policy to control groundwater use appears to be justified if the transaction costs are less than the costs of the externalities. Thus, even though it has been shown that the long-run recharge quota is not a "good" policy for reaching the true social value of the water resource, it can be used to control allocations so that the negative externalities are taken into consideration.

It appears, therefore, that a good case can be made for limiting the water pumped from the aquifer, unless there are opportunities for economically efficient transfers among basins on the surface through a market transfer process. If so, continued overdrafting would be justified only if the value of the transferred water at the margin were higher than the sum of the user costs, pumping costs, and transfer costs.

Pumping tax policy. An alternative policy for managing a groundwater basin that suffers from the problem of commonality of use is to levy a tax on pumping. This is a widely proposed solution to correct a divergence between private and social costs (Pigou). In this case the marginal private cost is simply the marginal cost of pumping to individual users. The marginal social cost includes as well the loss of productivity to individual users because of competitive pumping. The dominant problem with Pigovian solutions is the selection of the correct tax (Baumol). Milliman demonstrates that if the marginal value of a unit of water pumped is equated to the marginal social cost of pumping the water that a social optimum has been reached.

The necessary condition for the empirical model to allocate water optimally requires that the net marginal value of a unit of water used be equated to the transformed user cost. Because the marginal private pumping costs already have been subtracted from the marginal values, the transformed user cost actually measures the difference between the marginal social and marginal private cost of pumping a unit of water. As such, it represents the optimal marginal tax rate that is required to force private and social costs to converge.

Table 7 contains the optimal tax under a 4.5¢ energy cost scenario. The results listed in the table indicate that the optimal tax structure is not a fixed levy over the entire planning horizon, but is rather a declining set of tax rates. The table results raise other issues. First, all tax rates are positive. At first glance this may appear somewhat surprising given that three of the six basins indicate rising water tables after the 4.5¢ energy cost has been reached. Even with rising water tables, however, if an individual pumper did not extract a unit of water, the water table would rise somewhat higher than if the unit of water were extracted. This extraction thus increases the pumping costs of the other individuals using the aquifer.

In addition, the tax rates show a wide range

surface water would move toward a more socially efficient allocation. For example, if agricultural producers were allowed to bid for available water supplies, assured full property rights and perfect competition, they would bid the price up to the level of the marginal value of water utilized in production. Because the control model is based on exactly this type of allocation procedure, it is expected that surface allocation resulting from the "water market" arrangement would approximate the socially optimum allocation indicated by the control model.

The pro-rata groundwater policy. The prorata method is one that attacks the common pool problem by adjudicating annual groundwater quotas to overlying landowners. The quota most often recommended is established by restricting pumpage to the long-run mean recharge rate. This suggests that no mining of the resource should be permitted on the average.

Table 5 provides a comparison of the total value of the groundwater resource for the entire Yolo County aquifer under socially optimum conditions (no restrictions on temporal allocations of the resource in any basin) as opposed to a quota system, where the quota is limited to the mean recharge rate. This comparison is made under two energy cost scenarios and the results under both energy cost runs indicate that using a quota diminishes the potential social benefits to be derived from the resource. The 4.5¢ energy cost scenario shows a much wider divergence from the optimal social value, however, than does the 6.5¢ energy cost scenario. The percentage loss of social value under the 4.5¢ energy scenario ranges from 11% to 6% over the planning horizon, while for the 6.5¢ energy scenario the range is only 4.4% to 1.1%. As energy costs increase and the optimal amount of water to be used in any single period declines, the quota system comes closer to approximating the social value of the resource on a basin-wide basis.

From the above it is obvious that quotas will be least inefficient where the amount of water mining in the optimal allocation is small in relation to recharge. However, quotas always will be suboptimal if any economic mining of the resource is optimal, and their inefficiency will increase as transaction costs are taken into consideration. These costs would be in the form of administrating and policing the quota policy. The quota values listed in table 5 include none of these costs, and thus must be viewed as upper bounds and the differences are biased downwards. It should be noted here that this situation is not unique for quota policies. Any policy which controls the use of a common property resource in a more socially preferred manner probably would require a new institutional structure and therefore would require new transaction costs.

Laissez-faire groundwater policy. The inclusion of transaction costs in the calculus of considering policy changes creates the possibility that the status quo may offer the "best" that can be done in terms of maximizing the social value of the water resource. Table 6 compares the value of the groundwater of Yolo County under a purely private decision-making situation where each pumper decides independently how much water to take from the aquifer and the socially efficient situation where the negative externalities associated with private actions are taken into consideration. The user cost or stock value is assigned a zero value to represent the private allocation situation.

There is a large difference between the so-

Table 5. Yearly and Total Present Value of the Water Resource under Socially Efficient and Quota Allocations (1977–2010, $0.045/Kwh. and $0.065/Kwh.)

Energy Cost ($/Kwh.)	Value Measure	1977	1980	1985	1990	1995	2000	2005	2010	Total[a]
						($ thousand)				
0.045	Social	22,122	16,860	12,820	9,230	6,150	4,710	3,350		294,240
	Quota	19,619	15,224	11,710	8,530	5,730	4,410	3,150		268,750
	Difference	2,493	1,636	1,110	700	420	300	200		25,490
0.065	Social		19,185	13,781	9,840	7,160	5,160	3,720	2,830	259,160
	Quota		18,292	13,696	9,640	7,040	5,090	3,670	2,800	252,410
	Difference		893	412	200	120	70	50	30	6,750

[a] Represents total value of the water resource over the entire planning horizon.

groundwater basin in Yolo County as an aggregate unit would miss the sizeable variation in optimal utilization of the groundwater in the various basins composing the aquifer. These data show that the choice of a planning unit for determining optimal water allocations is very important. If the unit chosen is too large, and a single utilization rate were used throughout, groundwater mighe be seriously under- or over-utilized. Even more subdivision of the aquifer studied might have revealed even more variation in optimal utilization rates, but further analysis was infeasible.

Effects of rising energy costs. Energy costs can have an important influence on whether the model indicates a groundwater basin with an increasing or decreasing water table. For example, Upper Cache-Putah basin would be mined under a 2.6¢ energy cost assumption but would have a rising water table initially under the 8¢ energy cost assumption (fig. 1). The remaining basins move in the same direction as indicated in table 4 at alternative energy cost assumptions. In those basins where groundwater use exceeds recharge under a 4.5¢ energy cost, the effect of higher energy costs is to slow down the rate of mining.

Table 4 illustrates the impact increasing energy costs have on temporal water allocation, using the Cache Creek basin as an example. Surface water allocations depend upon the net marginal value of water in a single basin relative to the net marginal values in other competing basins. For Cache Creek, the allocations are reasonably constant over time. Groundwater pumpage at any time period decreases as expected as energy costs increase, because the net marginal value of water is lower and the stock value is higher.

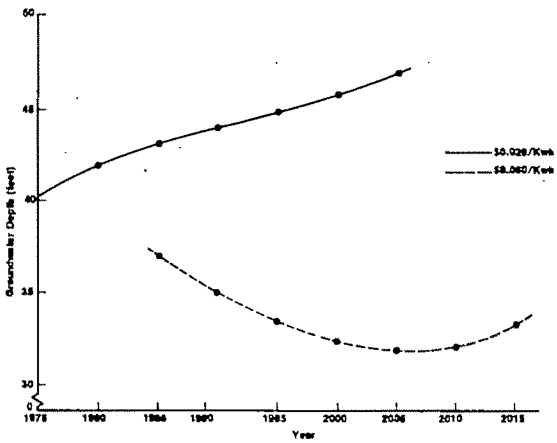

Figure 1. Impact of constant energy cost on Upper Cache-Putah Basin groundwater depth ($0.026/kwh. and $0.080/kwh., 1975–2015)

Policies to Reduce Misallocation of Groundwater

In this section two policies are analyzed empirically that could be utilized to achieve a more socially preferred allocation of groundwater. The focus here is on groundwater because of the lack of any definitive empirical studies which evaluate the impact of various policies on the social value of groundwater. This is not meant to infer that surface water allocation is unimportant. Quite to the contrary, surface water sources supply almost one-half the county's agricultural water demands.

The control model provided the socially efficient allocations of the surface water resource. If contractual arrangements were made on a "market value" rather than a "first come-first serve" arrangement, then

Table 4. Increasing Energy Cost Impacts on Temporal Surface and Groundwater Allocations, 1975–2015—Cache Creek Basin (acre-feet)

Energy Cost ($/Kwh.)	Water Supply	1975	1977	1980	1985	1990	1995	2000	2005	2010	2015
0.026	surface water	14,465	14,465	14,465	14,465	14,465	14,465	14,465	14,465		
	groundwater	51,714	51,748	51,790	51,850	51,932	52,148	52,887	54,073		
0.045	surface water		15,645	15,645	15,645	15,645	15,645	15,645	15,645		
	groundwater		47,525	47,586	47,663	47,747	47,926	48,504	50,567		
0.065	surface water			17,122	17,122	17,122	17,122	17,122	17,122	17,122	
	groundwater			42,533	43,012	43,082	43,204	43,566	44,832	47,980	
0.080	surface water				15,793	15,793	15,793	15,793	15,793	15,793	15,793
	groundwater				38,949	38,990	39,040	39,158	39,550	40,952	44,450

in net marginal values and also in user costs in the six basins indicate potentials for economic intra and interbasin transfers of groundwater.

Table 2 contains the optimal spatial and temporal allocation of groundwater and surface water suggested by the model under a 4.5¢ electrical power cost scenario. Several observations can be made about these results. The amount of groundwater used for agricultural production generally increases over time. Several economic factors determine the temporal allocation of water in the model. Factors which limit the quantity allocated to a specific period are (*a*) increased pumping costs for the remainder of the planning horizon for those basins having declining water tables and (*b*) lower marginal values from additional quantities of water used in that time period. The factors tending to increase the quantity used per period are (*a*) time preference reflected by the discount rate and (*b*) high net marginal values on low rates of water usage. The wide range of agricultural groundwater pumpages (0.0 to 141,690 acre-feet in 1980) illustrates quite dramatically the variability in optimal groundwater allocations that can exist in a single aquifer when both the economic and physical parameters in each basin are considered in the decision-making process.

Table 2 also contains urban groundwater allocations which are based on "need" projections. The projections are based on urban water requirement studies done by several engineering consulting firms, and by using an urban water projection model developed by Savage and Helweg for estimating the impact of population and areal growth patterns for water use rates for the City of Davis. The projections were used as constraints on urban allocations because early control model runs, based on the hypothetical urban demand functions estimated for this study, allocated certain amounts to the urban areas in excess of existing or projected distribution system capacity.

The amount of groundwater needed by urban users moves from 6.8% of the total amount of groundwater used in all basins in 1977 to 8.6% of the total by 2,005. This represents a small proportion of the total amount of groundwater used in any period. Thus, the impacts on groundwater stocks by urban usage is rather insignificant for any basin as a whole. This suggests that concern that urban growth will affect adversely agricultural pumpage and pumping cost is largely unfounded.

The surface water allocations shown in table 2 can be explained by the surface water cost used in this model: namely, those that existed in 1977 were selected due to the difficulty in predicting the future price-setting actions of the various agencies allocating surface water. Because surface water costs are substantially less than groundwater pumping costs, surface water allocations depend on the relative net marginal values of this water between the various basins and on the capacity of the distribution system. Surface water allocations are limited in every power cost scenario by constraints associated with either reservoir water distribution capacity or the amount of surface water that can be obtained from the Sacramento River-Colusa Drain complex. The surface water allocations listed in table 2 are thus constrained allocations.

Table 3 contains the groundwater depths and surface water stocks associated with the optimal allocations contained in table 2. Note that in three of the six basins the water table decreases over time, while in the remaining three it increases. This set of figures indicates quite strikingly that treating the whole

Table 3. Groundwater Depths and Surface Water Stocks (1977–2005, $0.045/Kwh.)

	Depth to Groundwater (feet)						
Groundwater Basin	1977	1980	1985	1990	1995	2000	2005
Cache Creek	64	69	74	77	80	81	82
Upper Cache-Putah	41	40	39	38	38	39	39
Plainfield Ridge	105	119	145	190	262	385	>420
Lower Cache-Putah	53	56	61	65	71	76	81
Colusa	55	50	45	42	41	40	41
East Yolo	20	18	15	13	12	11	11
	Effective Storage (acre-feet)						
Clear Lake	315,000	315,000	315,000	315,000	315,000	315,000	315,000
Indian Valley	138,789	139,574	139,857	139,893	139,893	139,893	139,893

marginal values, stock user costs, and transformed user costs associated with the groundwater allocations listed in table 2. Surface water stock values are not included in table 1 because the surface water distribution system constraint limits the amount of surface water which can be used in any period to less than would have been allocated in the unconstrained solution. This restriction increased the net marginal value of the surface water in any time period to a level greater than the existing reservoir user cost in that time period.

The stock user cost for all basins except Plainfield Ridge can be interpreted as the present value of the loss in social surplus if one more acre-foot were allocated for use in the specific time period. For example, if one more acre-foot of water were used from the Lower Cache-Putah basin than is socially optimal, the value of the stock would diminish by $149.58. The user cost figures given for Plainfield Ridge are not an accurate estimate of the true user cost because the lower bound constraint on the depth of the water table was reached. This constraint assumes that the volume of stored water associated with a depth greater than 420 feet is zero. Even though somewhat arbitrary, the lack of data on groundwater storage beneath 420 feet made the constraint necessary.

The transformed user costs are the present value of the stock in terms of current use. The transformation was made by the model to allocate water optimally between time periods. Note that the transformed user costs and net marginal values are approximately equal in each time period for each basin except Plainfield Ridge. Differences are due to rounding errors associated with use of the algorithm. It should be noted that these transformed user costs are a measure of the external costs that are imposed on other pumpers under the common property situation where private decision making on the part of individual users of the groundwater basins is based solely on private rather than the social cost of pumping a unit of water. Except for Plainfield Ridge, the extreme values of transformed user cost is $10.62 for Lower Cache-Putah and $2.66 for East Yolo. This indicates that different basins even in the same aquifer can exhibit different external costs. The magnitude of these costs can serve as at least one measure of whether or not governmental intervention into the allocative process is warranted. The differences

Table 2. Optimal Temporal Groundwater and Surface Water Allocations (1977–2005, $0.045/Kwh.)

		(Acre-Feet)						
Groundwater Basin	Water Supply	1977	1980	1985	1990	1995	2000	2005
Cache Creek	surface	15,646	15,646	15,646	15,646	15,646	15,646	15,646
	agriculture groundwater	47,525	47,586	47,663	47,747	47,926	48,504	50,567
Upper Cache-Putah	surface	91,955	91,955	91,955	91,955	91,955	91,955	91,955
	agriculture groundwater	33,859	33,872	33,967	34,251	34,982	36,825	41,361
	urban groundwater	1,344	2,073	2,234	2,394	2,394	2,394	2,394
Plainfield Ridge	surface	3,395	3,395	3,395	3,395	3,395	3,395	3,395
	agriculture groundwater	0	0	0	7,492	12,879	15,601	0
Lower Cache-Putah	surface	36,605	36,605	36,605	36,605	36,605	36,605	36,605
	agriculture groundwater	139,670	141,690	146,050	152,320	161,620	175,700	197,340
	urban groundwater	17,763	21,870	24,199	26,503	27,467	29,149	29,149
Colusa	surface	179,130	179,130	179,130	179,130	179,130	179,130	179,130
	agriculture groundwater	93,909	93,511	93,127	93,023	93,459	96,191	110,580
East Yolo	surface	130,870	130,870	130,870	130,870	130,870	130,870	130,870
	agriculture groundwater	59,571	59,548	59,527	59,536	59,628	60,054	61,904
	urban groundwater	8,289	10,427	11,051	11,629	12,926	13,528	13,528

(2) $y_t = Ay_{t-1} - Bu_{t-1} + Cx_{t-1} + \mathbf{d},$

(3) $y_t - y^*_t \leq 0,$

(4) $u_t - u^*_t \leq 0,$ and

(5) $y_t \geq 0 \quad u_t \geq 0.$

The welfare function [equation (1)] is an explicit economic measure of welfare. It is composed of two parts. Producer and consumer surplus measures the economic value of the flow component of the water resource base. The consumer surplus is associated with the urban sector demand functions, while the producer surplus represents economic rent available to the agricultural sector.[2] The second part is a social surplus for the stock portion of the water resource base. It measures the returns to the stock that could be gained from monopoly control. The social surplus increases as stocks increase and pumping costs decrease, *ceteris paribus*; and, alternatively, the social surplus decreases as stocks diminish and pumping costs increase. Note that these components are inversely related. The consumer and producer surplus components relate to flows and increase at a diminishing rate with increasing water use; however, as water use increases stocks diminish and the rents associated with this component decrease at an increasing rate. Thus, the model maximizes the value of the water resource base by equating the net marginal value of the flow to the opportunity cost or marginal value of the stock in that period.[3]

The welfare function is subject to two sets of constraints. The first set [equation (2)] is the equations of motion or first-order difference equations describing the physical system. This is a reduced-form system, which in this study is a linear approximation to a complex physical system. A, B, and C are specified as time invariant matrices and $\mathbf{d}$ is a vector of constants. The second set of constraints [equations (3), (4), and (5)] respresents the physical, institutional, and nonnegativity conditions on the stocks and flows of water. These constraints are not applied to every scenario posed by the model but rather act as individual scenario conditions so that resulting allocation patterns and effects on social welfare can be observed.

The Results

One reason for using an optimal control model was that it allowed direct calculation and interpretation of the user costs associated with temporal allocations. Table 1 presents the net

[2] This measure has been used by Samuelson and later Takayama and Judge to measure social welfare. Mishan discusses the assumptions of this approach to social welfare measurement.

[3] The net marginal value is defined as the marginal value of water net of water cost. A more detailed description of the empirical model and the analytical necessary conditions for achieving an optimal solution is contained in Noel.

Table 1. Stock User Costs, Net Marginal Values, and Transformed User Costs (1977–2005, $0.045/kwh.)

		Value (dollars/acre-foot)						
Groundwater Basin	Value Measure	1977	1980	1985	1990	1995	2000	2005
Cache Creek	stock user costs	28.79	23.15	16.19	11.33	7.79	4.93	1.94
	net marginal values	5.68	5.24	3.20	2.24	1.52	0.93	0.26
	transformed user costs	6.01	4.84	3.38	2.37	1.62	1.03	0.40
Upper Cache-Putah	stock user costs	30.00	24.47	17.32	12.06	8.05	4.76	1.67
	net marginal values	8.19	7.64	4.71	3.01	2.14	1.21	0.31
	transformed user costs	8.73	7.12	5.04	3.51	2.34	1.38	0.47
Plainfield Ridge	stock user costs	1,214.10	653.10	241.20	83.57	21.53	0.87	≈0.00
	net marginal values	61.13	61.13	61.13	13.06	3.03	≈0.0	≈0.00
	transformed user costs	240.39	129.32	47.77	16.55	4.26	0.17	≈0.00
Lower Cache-Putah	stock user costs	149.58	118.63	79.25	51.08	30.07	15.76	4.53
	net marginal values	9.83	7.81	5.17	3.30	1.94	0.94	0.18
	transformed user costs	10.62	8.42	5.63	3.63	2.13	1.12	0.32
Colusa	stock user costs	27.94	23.18	16.79	12.04	8.50	5.65	2.49
	net marginal values	7.10	5.88	4.25	3.04	1.95	1.37	0.43
	transformed user costs	7.66	6.35	4.60	3.30	2.33	1.55	0.68
East Yolo	stock user costs	12.23	10.06	7.22	5.14	3.60	2.35	0.99
	net marginal values	2.44	2.00	1.41	1.02	0.72	0.44	0.12
	transformed user costs	2.66	2.19	1.57	1.12	0.78	0.51	0.22

water resource system. They provided a theoretical framework in which a demand function for water is an integral part of an aquifer model. Gisser and Mercado (1972, 1973) also integrate the demand function for water into a hydrologic model.

The model proposed in this paper is a linear quadratic control model (LQCM) and is composed of two basic parts, (*a*) an economic component and (*b*) a hydrologic component. The economic component contains a derived demand model, a stock opportunity cost model, and an urban demand model. The derived demands are obtained from a linear programming model. The use of linear programming to develop demand functions for agricultural water is rationalized in Moore and Hedges and Gisser. The stock opportunity cost model is a set of marginal pumping cost functions which are estimated so that the stock value of the resource can be derived. Finally, urban demand functions were estimated by an indirect method so that the LQCM can allocate water efficiently between the two sectors.

The hydrologic component of the LQCM is comprised of a set of equations of motion for the surface water reservoirs and groundwater basins. The former are estimated from data obtained from a surface water hydrology model, while the latter are a set of simultaneous equations estimated from data obtained from a finite element groundwater model. These equations indicate the changes that will occur in groundwater depths, given various pumping and recharge rates and also account for subsurface flow between basins.

The LQCM maximizes the value of economic components subject to the constraints implied by the hydrologic component. This particular model extends previous work in several ways. First, there is a direct interaction in the LQCM between a complex multibasin aquifer-surface water system and the demands for water. Second, the LQCM is solved by an algorithm based on Pontryagin et al. maximum principle, which provides an advantage over other work using dynamic programming, which limits the number of state and control variables. Finally, the use of the LQCM allows direct calculation of the user cost of groundwater. Both Kelso and Renshaw discuss the importance of including stock values in determining optimal water allocation. By using the LQCM, it is possible to maximize the value of both the stock and current value components of the water resource simultaneously, thereby allowing the calculation of the socially optimal spatial and temporal allocation.

Application of the Conceptual Framework

The geographical setting, Yolo County, located in the southwest corner of the Sacramento Valley, was selected for several reasons. It provides an example of a region in which conjunctive use of groundwater and surface water has evolved without any particular centralized planning (California Department of Water Resources). Several water agencies have areas of jurisdiction within the county and most if not all of each agency's planning is independent of the others with decisions being made to maximize private rather than overall social value of the water.

The county has a highly variable supply of surface water from Clear Lake, Indian Valley Reservoir, and the Sacramento River-Colusa Drain complex, used almost exclusively for irrigation. Groundwater supplies a more costly but more dependable source of water to both agricultural and urban users. The aquifer was partitioned into six basins for modeling purposes and follows the work done by hydrologists Scott and Scalmanini. The partitioning permitted the model to allocate water spatially and took account of unequal pumping lifts throughout the aquifer. There was also the problem of unequal specific yields throughout the aquifer, and the division of the aquifer into several basins permitted specification of storage capacities reflecting yields. The division of the aquifer required that the subsurface inflows and outflows between the six basins be accounted for in the model. Burt (1974) developed an approximately optimal decision rule where the subsurface flow between two basins in the same aquifer is explicitly contained in the model. For the model reported here, the subsurface flow is calculated by the groundwater model. Thus, the coefficients of the groundwater stock variables contain the effects of the subsurface flow term.

The LQCM used for determining allocations of water resources in Yolo County can be represented as follows:

$$\text{(1)}\quad \text{Max}\quad W = RR'u_t - \tfrac{1}{2}u_t'Ru_t - KK'y_t + y_t'Ky_t,$$

subject to

Optimal Regional Conjunctive Water Management

Jay E. Noel, B. Delworth Gardner, and Charles V. Moore

An optimal control model is used to determine the socially optimal spatial and temporal allocation of groundwater and surface water among agricultural and urban uses. The control model is described briefly and its advantages over other dynamic models are enumerated. Optimal rates of groundwater pumpage over the planning horizon were highly sensitive to increasing energy costs. Groundwater basins are shown to react differently to alternative economic and hydrological parameters. In a dynamic setting, a policy of pump taxes was shown empirically to be superior to pro-rata quotas and uncontrolled pumpage.

Key words: control model, groundwater, energy cost, pro-rata allocation, Pigovian taxation.

The severe drought in the western United States in 1976–78 brought the problems of allocating extremely limited water resources to the attention of agriculturalists and urbanites alike. Greatly reduced surface water supplies exacerbated the already critical pressure on remaining groundwater stocks in the same areas.

The chronic overdraft of many western states groundwater basins can be attributed directly to their common pool nature. The lack of explicit property rights to groundwater stocks results in individual users of the resource evaluating only their own private pumping costs in their decision framework and implicitly assigning a zero opportunity cost to the stock portion of the resource. Thus, the private decision does not take into account any user cost and results in a divergence in the private and the social optimal rate of pumping.[1]

The objective of this paper is to describe briefly an optimal control model which can be used to determine the socially optimal spatial and temporal allocation of groundwater and surface water among agricultural and urban uses. The control model is then applied to a representative region of California under several sets of energy costs. Two policies, pro-rata allocation and taxation, are evaluated empirically as alternatives for accounting for externalities due to the common pool problem.

The Conceptual Framework

Several authors have investigated the conjunctive use of groundwater and surface water using various techniques. Buras developed a dynamic programming algorithm to solve the problem of conjunctive use of reservoirs and aquifers. His operating policy, however, considered the physical system as a single unit and thus ignored differences in hydrology that occur in a complex groundwater system. Burt (1964, 1966, 1967a, b) utilized a mathematical programming approach to develop a demand function for irrigation water used in a dynamic programming formulation of the aquifer management problem. Bredehoeft and Young used a simulation model to estimate the solution of problems involving the development of a stream-aquifer system in an economic model of irrigation. Bear and Levin studied optimal utilization of an aquifer as one element of a

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[1] Scott defines user cost of a natural resource as "the present value of future profit foregone by a decision to produce a unit of output today." Although this definition is used in the context of a profit-maximizing firm, it also applies to the water resource problem and refers to the existence value of the stock.

various formats which may be used for iterative bidding, it seems that formats which directly observe *WTP* are most effective. There are reasons to expect that WTP^C formats usually would be most effective of all because they assume correspondence between the subject's initial welfare level and his reference welfare level, without relying on the notion of compensation payments.

The results of our hypothesis tests suggest that, in contexts where compensation is not customarily paid to those who experience decrements in natural and environmental amenities, iterative bidding formats for the direct observation of WTA^C do not appear to collect reliable value data. In such contexts, it remains possible to estimate WTA^C by collecting data in the form of *WTP* (preferably, WTP^C) and using the theoretical relationships developed by Randall and Stoll to derive WTA^C.

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References

Bradford, D. F. "Benefit-cost Analysis and the Demand for Public Goods." *Kyklos* 23(1970):775–91.

Brookshire, D. S., B. Ives, and W. Schulze. "The Valuation of Aesthetic Preferences." *J. Environ. Econ. Manage.* 3(1976):325–46.

Cocheba, D. J., and W. A. Langford. "Wildlife Valuation: The Collective Good Aspect of Hunting." *Land Econ.* 54(1978):490–504.

Currie, J. M., J. A. Murphy, and A. Schmitz. "The Concept of Economic Surplus and Its Use in Economic Analysis." *Econ. J.* 81(1971):741–99.

Hicks, J. R. "The Four Consumer's Surpluses." *Rev. Econ. Stud.* 11(1943):31–41.

Mishan, E. J. *Cost-Benefit Analysis: An Introduction.* New York: Praeger Publishers, 1971.

———. "The Use of Compensating and Equivalent Variations in Cost-Benefit Analysis." *Economica* 43(1976):185–97.

Randall, A., B. C. Ives, and E. Eastman. "Bidding Games for Valuation of Aesthetic Environmental Improvements." *J. Environ. Econ. Manage.* 1(1974):132–49.

Randall, A., O. Grunewald, S. Johnson, R. Ausness, and A. Pagoulatos. "Reclaiming Coal Surface Mines in Central Appalachia: A Case Study of the Benefits and Costs." *Land Econ.* 54(1978):472–89.

Randall, A., and J. Stoll. "Consumer's Surplus in Commodity Space." *Amer. Econ. Review* in press.

Willig, R. D. "Consumer's Surplus without Apology." *Amer. Econ. Rev.* 66(1976):587–97.

Table 2. Observed WTP^E and Derived WTP^C

Segment (# of Encounters)		WTP^E (Observed)	WTP^C (Derived)	Not Significantly Different at[a]
0.1,1	Mean ($)	43.64	12.74	
	N	11	55	
	S	42.55	54.95	.05
	$S_{\bar{x}}$	12.83	7.41	
1,5	Mean ($)	54.06	33.48	
	N	16	58	
	S	69.05	75.63	.20
	$S_{\bar{x}}$	17.26	9.93	
5,10	Mean ($)	32.00	19.47	
	N	15	58	
	S	21.28	58.33	.40
	$S_{\bar{x}}$	5.49	7.66	

Note: N is the number of observations, S is the standard deviation, and $S_{\bar{x}}$ is the standard error of the mean.

[a] The hypothesis test was $H_0:\mu_1 = \mu_2$; $H_1:\mu_1 \neq \mu_2$. If the calculated $|t^*|$ was greater than the critical value $t_{n_1+n_2-2},\ 1-\frac{\alpha}{2}$, H_0 was rejected. Thus, by failing to reject H_0, we infer that the two means are not significantly different at the chosen level of confidence.

served WTP^E was not significantly different from derived WTP^C. However, observed WTA^C was significantly different from, and up to an order of magnitude greater than, derived WTA^C. In addition, 54% of the subjects confronted with formats to obtain observed WTA^C refused to accept any finite amount of compensation, and were eliminated from the analysis to test H_2.

set) are of similar empirical magnitude. As Willig and Randall and Stoll demonstrate, *WTP* and *WTA* are of similar magnitude when the "income effect" is small and the total value of the good represents only a small proportion of the total budget. Where these conditions do not hold, one can expect larger differences between *WTP* and *WTA*.

Conclusions

We have derived the theoretical relationships between various measures of value and shown that, in any particular situation, the proper measure of value can be identified on the basis of theoretical considerations. Of particular importance, to implement the benefit-cost criterion (i.e., the potential Pareto-improvement) estimates of *WTA* for decrements in goods, services, and amenities are required.

While the total value model places no restrictions on the methods by which data may be collected, the iterative bidding method of contingent valuation has been found to be an effective data collection mechanism. Of the

Table 3. Observed and Derived WTA^C

Segment (# of Encounters)		WTA^C (Observed)	WTA^C (Derived)	Significantly Different at[a]
0.1,1	Mean ($)	68.52	12.74	
	N	10	55	
	S	95.08	54.95	.02
	$S_{\bar{x}}$	30.07	7.41	
1,5	Mean ($)	142.60	33.49	
	N	12	58	
	S	142.68	75.63	.01
	$S_{\bar{x}}$	41.19	9.93	
5,10	Mean ($)	207.07	19.48	
	N	9	58	
	S	121.51	58.33	.01
	$S_{\bar{x}}$	40.50	7.66	

Note: N is the number of observations; S is the standard deviation; and $S_{\bar{x}}$ is the standard error of the mean.

[a] The hypothesis test was $H_0:\mu_1 = \mu_2$; $H_1:\mu_1 \neq \mu_2$. If the calculated $|t^*|$ was greater than the critical value $t_{n_1+n_2-2},\ 1-\frac{\alpha}{2}$, H_0 was rejected.

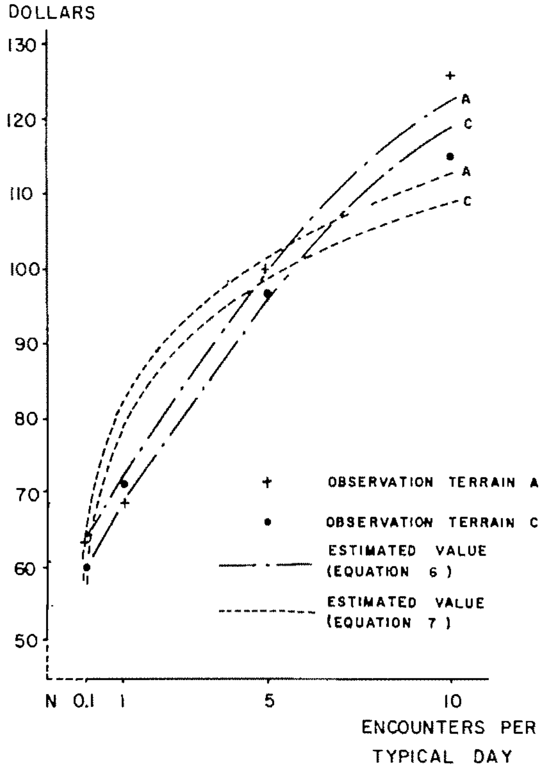

Figure 4. Mean (per hunter) annual value of the right to hunt elk, Laramie, Wyoming, 1977–78, as influenced by hunting environment and frequency of encounter with elk

An additional equation (9), which differed from (8) only in that the dependent variable was *Indbid* (i.e., individual bid for each *Encl Environ* combination) was also estimated. For equation (9), the R^2 was only .09 and the coefficient for ln(*Income*) was insignificant. The procedure of using mean bids for income groups as the dependent variable [equation (8)] results in a substantial reduction in mean square error, MSE [.224 for equation (8), as opposed to 1.80 for equation (9)], at the expense of increased magnitudes of the principle diagonal elements of the inverse transpose matrix (table 1).

Comparison of results obtained with WTP^C, WTP^E and WTA^C formats. The results of valuation exercises for the same good using WTP^C, WTP^E, and WTA^C formats may be different for two reasons: (*a*) as a result of "income effects," the different measures of consumer's surplus are empirically different, and (*b*) subjects may react differently to different contingent market formats. Subjects may take offense at WTP^E formats, which face the subject with an inferior reference level of welfare. Subjects who are not accustomed to being offered compensation for losses in natural and environmental amenities may find WTA^C formats incredible and unrealistic, or they could interpret WTA^C formats as providing an opportunity for making strong statements about a set of rights which seems fairer than the rights which actually exist ("If the choice were mine, I would not let them decimate elk populations for anything!"). Because WTP^C formats are based on correspondence between the subject's initial and reference welfare levels without relying on the notion of compensation payments, there seems little reason to expect WTP^C formats to encounter the resistance and difficulties which may confront WTP^E and WTA^C formats.

The bounds on the difference between *WTA* and *WTP* (Randall and Stoll) permit the precise calculation of the differences in results which may be attributed to income effects. Once these differences are accounted for, any remaining differences in results must be attributable to differential efficacy of WTP^C, WTP^E, and WTA^C formats as data collection devices.

From the raw data set used to estimate equations (6)–(9), estimates of WTP^C for increments in elk populations such that frequency of encounter would increase from 0.1 to 1, 1 to 5, and 5 to 10, and WTA^C for decrements across the same ranges, were derived, using the formula, $WTA - WTP = \frac{\zeta M^2}{Y}$. In order to test the following two hypotheses:

H_1: observed WTP^E = derived WTP^C, and
H_2: observed WTA^C = derived WTA^C,

observations of WTP^E and WTA^C for decrements across these three ranges were obtained using subsamples and iterative bidding formats which were different from those which provided the data used to estimate derived WTP^C and WTA^C.

The results of the tests of H_1 and H_2 are presented in tables 2 and 3, respectively.[5] Ob-

retrospect, that the iterative bidding procedure was a "waste of time" and "hard to take seriously"; and *Acc* 2 is probability . . . thought, in retrospect, that his own response to the iterative bidding procedure was "a poor guide for game management policy." The coefficient for each of these additional variables had the expected sign. *Acc* 1 and *Acc* 2 enable identification of the proportion, in each income category, of individuals whose acceptance of the contingent valuation procedure was poor.

[5] Examination of tables 2 and 3 indicates that derived WTP^C and derived WTA^C (both of which were derived from the same data

Table 1. Estimated Bid Equations

Equation	Dependent Variable	Intercept	*ENC*	ENC^2	ln(*ENC*)	*ENVIRON*	ln (*INCOME*)	$\bar{R}^2$ / *N* / *F*
		Estimated Coefficients (Standard Errors)						
(6)	Meanbid for each *ENC/ENVIRON* combination.	63.251** (2.421)	8.750** (1.268)	−.284* (.112)		−3.550 (2.505)		.98 / 8[a] / 117.21
(7)	ln(*Meanbid*) for each *ENC/ENVIRON* combination	4.395** (.059)			.142** (.023)	−.033 (.082)		.83 / 8[a] / 18.71
(8)	ln(*Bid*) for each *ENC/ENVIRON* combination, for each income group	1.189 (1.125)			.188** (.047)	.107 (.167)	.306** (.115)	.40 / 32[b] / 7.79
	Principal diagonal $(X'X)^{-1}$	5.652			.010	.125	.060	MSE = .224
(9)	ln(*Indbid*) for each *ENC/ENVIRON* combination	2.916** (1.020)			.253** (.046)	.008 (.170)	.082 (.104)	.09 / 290[c] / 10.12
	Principal diagonal $(X'X)^{-1}$	.577			.001	.016	.006	MSE = 1.80

Note: * indicates significant at the .1 level of confidence; ** is significant at the .01 level of confidence.
[a] Eight combinations of 4 levels of *ENC*, and 2 *ENVIRON*s.
[b] Thirty-two combinations of 4 levels of *ENC*, 2 *ENVIRON*s, and 4 income groups.
[c] Five bids (4 levels of *ENC* at typical *ENVIRON*, plus 1 level of *ENC* at atypical *ENVIRON*) for 58 respondents.

Enc/Environ combination, and *Income* is mean income ($/year) for each income category.

In estimating equation (8), the sample was divided into these four income categories:

Income Category	Income Range ($/year)	Number of Observations	Mean Income ($/year)
1	Income ≤ 10,000	12	5,592
2	10,001 ≤ Income ≤ 18,000	17	14,500
3	18,001 ≤ Income ≤ 26,000	15	21,433
4	26,001 ≤ Income	14	41,508

Because the number of observations in each category is similar, this procedure should not introduce serious heteroskedasticity problems. Coefficients for ln(*Enc*) and ln(*Income*) were highly significant, while the coefficient for *Environ* was again insignificant (table 1). Note that, when an equation such as (8) is estimated, the coefficient for ln(*Income*) is an estimate of ζ. The adjusted R^2 was 0.4. Again, the F-statistic for the entire equation was significant at the .01 level. When the model of equation (8) was re-estimated with four additional variables (sex of subject, subject did/did not kill an elk last season, and two variables indicating the respondent's degree of acceptance of the contingent valuation procedure) a marked increase in R^2 was noted, while the coefficient for *Enc* and *Income* changed only slightly, in each case becoming a little larger and more significant statistically.[4]

[4] The estimated equation was

$$\begin{aligned}\ln(Bid) &= \underset{}{1.563} + \underset{(.026)}{.197}\ln(Enc) + \underset{(.096)}{.369}\ln(Income) + \underset{(.296)}{.727}\,Kill\\ &\quad - \underset{(.654)}{1.017}\,Sex - \underset{(.349)}{.697}\,Acc\ 1 - \underset{(.383)}{3.096}\,Acc\ 2,\\ &\qquad R^2 = .83,\ N = 32,\ F = 27.10\end{aligned}$$

where *Kill* is probability that a randomly selected member of the income category killed an elk in the previous hunting season; *Sex* is probability . . . is a female; *Acc* 1 is probability . . . thought, in

population levels to the various sources of utility which the individual derives from the elk hunting experience.

The raw value data were collected using the iterative bidding technique (Randall, Ives, Eastman; Brookshire, Ives, Schulze; Randall et al.). Each iterative bidding format established a contingent market (a scenario which includes a complete description of the good to be "traded," the institutional structure within which "trade" takes place, and the subject's assumed initial situation and reference level of welfare), posited a starting level of total value, and conducted an iterative bidding process until the subject's actual total value (i.e., maximum *WTP*, or minimum *WTA*) was identified. Formats were designed to obtain estimates of WTP^C for increments in the quality of wildlife-related amenities, WTP^E to avoid decrements, and WTA^C to permit decrements.

Each survey schedule included two iterative bidding formats, a record of the subject's hunting activity, various questions designed to elicit information on the subject's attitudes relevant to hunting, and a confidential "feedback" section in which the subject could express his reaction to the interview and the contingent valuation exercise.

Analysis and Results

Previous studies (e.g., Brookshire, Ives, Schulze) have identified several sources of potential bias in value data collected with iterative bidding methods. Thus, preliminary analysis of the data collected in this case study included statistical tests for bias. The hypotheses that final value data were influenced by the initial bids posited to respondents, or by the particular interviewer who collected the data, were rejected at the .05 level of significance. The hypothesis that final bids (i.e., estimates of TV) were influenced by the choice of bidding vehicle (a component of the bidding scenario) was rejected at the 0.1 level of significance. Nevertheless, it was observed that refusal to bid, with *WTP* formats, occurred in six of fifty cases with a "utility bill" vehicle, but in none of fifty-eight cases with a "hunting license fee" vehicle. Negative comments in the "feedback" section occurred more frequently with the "utility bill" vehicle.[3]

[3] "Utility bill" vehicles were used because the sponsor expressed an interest in attempting to estimate directly preferences with respect to the trade-off between energy production and wildlife habitat in certain western states.

Although three terrains were included in the research design, no hunter in the sample typically hunted in terrain B. Thus, since the survey format collected a complete set of information for each subject's "typical" terrain and encounter frequency but only a subset of the possible information for "atypical" terrains, the data set for terrain B was incomplete. Therefore, further analyses consider frequency of encounter 0.1, 1, 5, and 10, and terrain A and C.

Using WTP^E data provided by fifty-eight subjects working with the "hunting license fee" bidding vehicle, the mean bid curve (or, mean total value curve) corresponding to curve 5′ in figure 3 was estimated, using two functional forms:

$$(6)\quad Meanbid = \beta_0 + \beta_1\, Enc + \beta_2\, Enc^2 + \beta_3\, Environ + \epsilon, \text{ and}$$

$$(7)\quad \ln(Meanbid) = \beta_0 + \beta_1 \ln(Enc) + \beta_2\, Environ + \epsilon,$$

where *Meanbid* is the mean of fifty-eight respondents' total value bids for each of the eight *Enc/Environ* combinations, in dollars per year; *Enc* is the frequency of encounters with elk on a typical day of hunting (0.1, 1, 5, 10), and *Environ* is a qualitative variable taking the value 1 for terrain C and the value 0 for terrain A.

The results of estimation are shown in table 1 and figure 4. Coefficients for *Enc* and ln(*Enc*) [equations (6) and (7)] and Enc^2 [equation (6)] were statistically significant at the .01 and .10 levels, respectively, while the coefficients for *Environ* were insignificant. The *F*-statistics led to rejection of the hypothesis that all parameters are equal to zero at the .01 level of significance. To determine the aggregate sample bid for each *Enc/Environ* combination, *Meanbid* may be multiplied by the sample size (i.e., 58). To estimate the aggregate bid for the population, *Meanbid* may be multiplied by the population size.

The "income effect". The price flexibility of income for the good, ζ, was identified as the key variable permitting rigorous calculation of the empirical value of *WTA* from *WTP* data or vice-versa (i.e., permitting correction for the "income effect"). To calculate ζ for elk-hunting amenities, equation (8) was estimated,

$$(8)\quad \ln(Bid) = \beta_0 + \beta_1 \ln(Enc) + \beta_2 \ln(Income) + \beta_3\, Environ + \epsilon,$$

where *Bid* is the mean of the total value bids of respondents in each income category for each

pation in elk hunting; Q', participation with frequency of encounter, Q'; and Q'', participation with frequency of encounter, Q''.[1] It is conceivable that the hunter could find himself in any one of three initial situations: N, Y^0; Q', Y^0; or Q'', Y^0. Given these three initial situations, a family of three total value curves may be defined (fig. 3):

$$(5')\quad U(N,Y^0) = U(Q',Y^{-b}) = u(Q'',Y^{-c}),$$

$$(5'')\quad U(Q',Y^0) = U(N,Y^{+a}) = U(Q'',Y^{-a}),$$

$$(5''')\quad U(Q'',Y^0) = U(Q',Y^{+b}) = U(N,Y^{+c}),$$

where $N < Q' < Q''$ and $Y^{-c} < Y^{-b} < Y^{-a} < Y^0 < Y^{+a} < Y^{+b} < Y^{+c}$. Consider the income axis: $Y^0 - Y^{-a}$, $Y^0 - Y^{-b}$, and $Y^0 - Y^{-c}$ are measures of *WTP*, while $Y^{+a} - Y^0$, $Y^{+b} - Y^0$, and $Y^{+c} - Y^0$ are measures of *WTA*.

This family of total value curves permits estimation of the annual value of elk-hunting amenities using data provided in a wide variety of forms. For example, curve (5′) may be fitted, using data on *WTP* for an elk-hunting license when the hunter expects frequency of encounter Q' and Q''. Curve (5″) permits the analysis of data indicating WTP^C for an increment in frequency of encounter from Q' to Q'', and WTA^C of a hunter currently enjoying participation with frequency of encounter Q' to accept nonparticipation. Curve (5‴) permits analysis of data for WTA^C of a hunter currently enjoying participation with frequency of encounter Q'' for a reduction in elk populations such as that his frequency would become Q', and WTA^C to accept nonparticipation in hunting. Empirical estimates of Hicksian equivalent value measures also may be used to derive this family of curves. Equivalent measures simply assume that the reference level of welfare (or presumed right) is different from the initial situation. For example, $Y^0 - Y^{-c}$ is equal to the WTP^E of a hunter currently enjoying Q'', Y^0 to avoid nonparticipation in hunting.

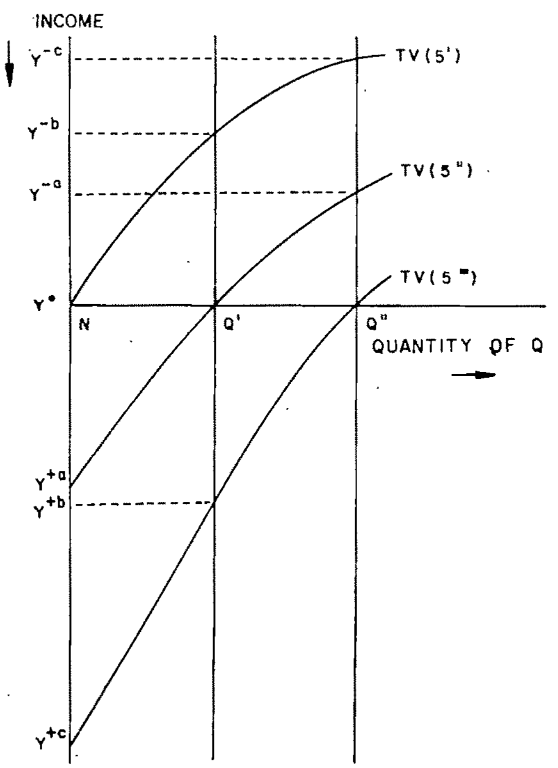

Figure 3. Total value curves for wildlife-related amenities, Q

Data Collection

In 1977 and 1978, an extensive pilot study was conducted in the vicinity of Laramie, Wyoming, for the purposes of (*a*) testing the general value model in application and (*b*) field testing a variety of contingent valuation methods for collecting value data for a considerable variety of wildlife-related amenities. The two purposes are logically distinguishable. That is, the general valuation model provides a conceptual framework for organization of empirical data obtained using any acceptable technique. The terms, *WTP* and *WTA*, do not per se imply data collection via contingent valuation. As a part of this study, 108 licensed elk hunters were interviewed.[2]

The "good" to be valued was the right to hunt elk, for one annual season, at various levels of hunting amenities. The amenities related to elk hunting were quantified in two dimensions: the terrain in which elk hunting takes place (A. foothills; B. plains; C. mountains); and the population of elk in the hunt area, which was indicated by the frequency of encounter with elk (0.1, 1, 5, or 10 elk encountered per day of hunting). These dimensions are sufficient to permit variation in the contributions of hunting environment and elk

[1] Compare our approach with that of Cocheba and Langford. They distinguished between an exclusive good aspect (game taken) and a collective good aspect (missed shots) of the hunting experience. We emphasize the collective good aspect, which we quantify in terms of "frequency of encounter" with elk.

[2] The pilot study was supported by the U.S. Fish and Wildlife Service (under Grant 14-16-0009-002), the Kentucky Agricultural Experiment Station and the Resource and Environmental Economics Laboratory of the University of Wyoming.

pensating and equivalent variation measures of the welfare impact of price changes.

In benefit-cost analysis, however, the immediate concern is the evaluation of the welfare impact of changes in the levels of goods, services, or amenities provided, rather than changes in price levels. In such cases, it is convenient to work with the terms *WTP* and *WTA* (thus rendering the absolute value terminology unnecessary). A general rule can be stated: $WTP \leq M \leq WTA$ (Randall and Stoll). Returning to the specific situation of the example used in figure 2,

$$(4) \quad WTP^E = WTP^C \leq WTA^C = WTA^E.$$

Two questions remain: (*a*) under what conditions are *WTP* and *WTA* equal, and (*b*) when $WTP < WTA$, can bounds on the difference be defined rigorously? The findings of Randall and Stoll, building on the work of Willig, may be summarized.

(*a*) For goods which are perfectly divisible and exchanged at zero transactions costs in infinitely large markets, *WTP* and *WTA* are equal and are equal to the price multiplied by the quantity change. In figure 1, the total value curve may be replaced with the price line. When the good whose quantity is subject to change has the characteristics of currency, and the proposed change is thus conceptually equivalent to a lump sum tax, *WTA* to permit the tax is equal to *WTP* to avoid the tax, and both are equal to the tax itself. The general total value model thus generates the primary result of partial equilibrium microeconomics (i.e., price equals unit value at the margin), as a special and limiting case. Market price is the appropriate measure of unit value lost or gained, when the good under consideration is perfectly divisible and may be exchanged at zero transactions costs in infinitely large markets.

(*b*) For goods which are indivisible or lumpy and can be held only in quantities Q^- and Q^0 (fig. 2), *WTP* is less than *WTA* (except when the income effect is zero). The difference between *WTA* and *WTP* may be approximated by $WTA - WTP = \dfrac{\zeta M^2}{Y}$, where

$\zeta = \dfrac{\partial P(Q,Y)}{\partial Y} \dfrac{Y}{P(Q,Y)}$, i.e., the price flexibility of income for the good, Q. This approximate bound on the difference between *WTA* and *WTP* is valid when ζ is constant and $\zeta M/2Y$ is relatively small (say, equal to or less than .05). Randall and Stoll also provide more rigorous bounds, which are appropriate when ζ is not constant and when $\zeta M/2Y$ is relatively large.

For divisible goods traded in costly markets (i.e., those where transactions costs are positive) the difference between *WTA* and *WTP* will be greater than zero, but no greater than the bounds discussed immediately above. The result of case (*a*) is predicated upon costless post-change adjustments in holdings, while that of case (*b*) is predicated upon the impossibility of post-change adjustments. Prohibitive transactions costs and indivisibility are both sufficient to preclude such adjustments. Thus, the difference between *WTP* and *WTA* in the positive transactions costs situation will never exceed the difference found in the case of indivisibility.

Annual User Values for Wildlife-Related Amenities

Consider a hunter who obtains utility from the right to hunt elk. This right is customarily granted by state agencies, in exchange for a license fee, and subject to restrictions upon hunting season, the number and type of elk taken and, often, on the region in which hunting takes place. The hunter derives utility from the environment in which he hunts; the exercise of hunting skills; the encounter with elk; and, perhaps, the taking of an elk. Frequency of encounter and probability of taking an elk vary with elk population. Enjoyment of the environment and the opportunity to exercise hunting skills may vary with the location of the hunt and, in addition, the hunter may perceive these things to be related to elk populations.

The elk is a fugitive resource which, while living, is unowned, and which may be converted to an exclusive good only at the successful completion of the hunt. Enjoyment of the environment, the opportunity to develop and display hunting skills, and the encounter with elk are all collective goods which are nonrival in consumption until the hunter population becomes so large that congestion reduces the utility of individual hunters.

The General Value Model for Elk-Hunting Amenities

Consider three levels of provision of the amenity, the annual right to hunt elk: N, nonpartici-

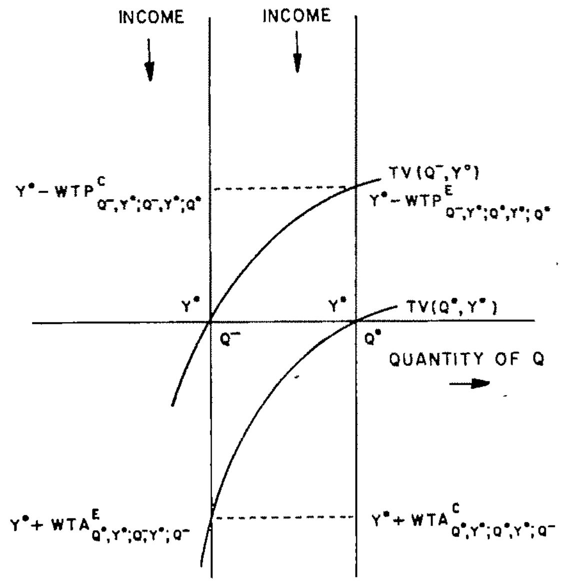

Figure 2. The relationships between *WTP* and *WTA*, and Hicksian compensating and equivalent measures of consumer's surplus

denoted $WTP^E_{Q^-,Y^0;Q^0,Y^0;Q^0}$. The superscript indicates that it is a Hicksian equivalent measure of value. The first subscript pair indicates that the reference level of welfare (or, if you will, the individual's presumed right) is taken to be Q^-, Y^0. The second subscript pair indicates that the individual's initial state is Q^0, Y^0. The third subscript indicates that, after the individual has paid, he will be permitted to enjoy the Q^0 level of amenities; if he pays exactly his *WTP*, his final income will be $Y^0 - WTP^E$.

Notice that the initial welfare level is different from the reference welfare level. That is the distinguishing feature of Hicksian equivalent measures. Compensating measures, on the other hand, assume that the initial situation is the reference welfare level. WTP^E cannot be found using a total value curve passing through the individual's initial state. It can only be found using another total value curve, which passes through the individual's reference level of welfare (fig. 2).

At this point, it occurs to us that the pair of total value curves shown in figure 2 may also be used to estimate the value to the same individual of a different project: a project which would increase the level of provision of wildlife-related amenities from an initial level Q^- to a "with project" level Q^0. For evaluating this project, the individual's initial situation is Q^-, Y^0. His willingness to pay for the increment in wildlife-related amenities the project would provide is $WTP^C_{Q^-,Y^0;Q^-,Y^0;Q^0}$. It is a compensating measure, since the reference level of welfare is the same as the individual's initial welfare level. A *WTA* measure can also be defined: $WTA^E_{Q^0,Y^0;Q^-,Y^0;Q^-}$. This is the individual's willingness to accept compensation in lieu of a promised increment in wildlife-related amenities from Q^- to Q^0. It is an equivalent measure, since the reference level of welfare is not the same as the individual's initial welfare level. It cannot be estimated from the total value curve passing through the individual's initial welfare level, Q^-, Y^0, but must be estimated from a new total value curve passing through the individual's reference welfare level, Q^0, Y^0.

The foregoing example makes a number of points. The Hicksian compensating measures of value of alternative levels of provision of a good, service, or amenity can be determined from a single total value curve, while equivalent measures of value must be estimated using a series of different total value curves, one passing through each of the possible levels of provision under consideration. When comparing two alternative levels of provision of a good (as in fig. 2), there are four relevant Hicksian value measures: WTP^C to obtain the preferred level; WTP^E to avoid the less preferred level; WTA^C to accept the less preferred level; and WTA^E to forego a promised increment to the preferred level. There is a compensating and equivalent version of *WTP*, as there is of *WTA*. Figure 2 suggests that, when comparing any pair of alternative levels of provision of a good, service, or amenity, WTP^C is equal in value to WTP^E, while WTA^C is equal in value to WTA^E.

The Relative Magnitudes of the Compensating and Equivalent Measures of Consumer's Surplus

The concept of consumer's surplus is most commonly used, as in Currie, Murphy, and Schmitz, to analyze the welfare impacts of price changes. It generally is concluded that (in absolute value terms) for price increases, $EV \leq M \leq CV$ and, for price decreases, $CV \leq M \leq EV$ (where *CV* is compensating variation, *EV* is equivalent variation, and *M* is Marshallian consumer's surplus). Willig rigorously derived empirically operational bounds on the magnitude of the differences between com-

often can be rigorously derived from estimates of other more readily available value measures.

Hicks showed that there are four measures of consumer's surplus, none of which is conceptually identical to the Marshallian measure. These are equivalent surplus, equivalent variation, compensating surplus, and compensating variation. The surpluses differ from the variations in that the latter are calculated after the consumer has made optimizing adjustments in his consumption set, while the former do not permit such adjustments. In general, the variations should be used when such optimizing adjustments are possible. However, benefit-cost analysts often encounter situations where optimizing adjustments are prohibited: once project or program specifications have been determined, the individual must take these as given. Thus there will be circumstances in which the Hicksian surpluses are appropriate.

The difference between the Hicksian compensating and equivalent measures of consumer's surplus is considerably more significant. The equivalent measure is defined as the amount of compensation, paid or received, which would bring the consumer to his subsequent welfare level if the change did not take place. The compensating measure is defined as the amount of compensation, paid or received, which would keep the consumer at his initial welfare level if the change did take place.

The Hicksian compensating and equivalent measures of consumer's surplus are both measures of the welfare impacts of changes, but they differ with respect to the reference level of welfare. The compensating measure, by using the initial welfare level as the reference level, measures the welfare impact of changes as if the individual had a right to his initial level of welfare (that is, as if he had the choice of keeping what he has or voluntarily trading for changes). The equivalent measure, by using the subsequent welfare level as the reference level, treats the individual as if he had only a right to his subsequent level of welfare (that is, as if he must accept his subsequent situation, or seek to trade his way back to his initial situation). Clearly, Hicksian compensating measures are consistent with the potential Pareto-improvement criterion, while Hicksian equivalent measures are not.

To clarify the relationship between Hicksian compensating and equivalent measures of value, *WTA* and *WTP*, and the total value curve introduced in figure 1, consider the following example. The benefit-cost analyst is evaluating a proposed project which would, among other things, divert a specified area of wildlife habitat to some alternative use, effectively destroying its usefulness as habitat. The benefit-cost analyst needs to know, among other things, the value of the losses which would be suffered by an individual who currently enjoys the wildlife amenities provided by that habitat. In the "without project" situation, the individual has the utility level $U(Q^0, Y^0)$. To keep the example simple, assume that this individual gains no benefits from the project. Thus his "with project" utility level would be $U(Q^-, Y^0)$. The level of Q, either the "without project" level Q^0 or the "with project" level Q^-, is predetermined so that optimizing adjustments are impossible.

What is the welfare impact of the proposed change on this individual? One could determine his *WTA* to accept the proposed change. Let us call this $WTA^C_{Q^0,Y^0;Q^0,Y^0;Q^-}$. The superscript C indicates that this is a Hicksian compensating measure of value, the first subscript pair, Q^0, Y^0, indicates that the individual's reference level of welfare (or his presumed right) is Q^0, Y^0. The second subscript pair indicates that Q^0, Y^0 is also his initial welfare level. The third subscript, Q^-, indicates the level of provision of wildlife-related services the individual would enjoy after he has accepted the compensation and the change in habitat-related services; if it turned out that he were compensated with an amount exactly equal to his *WTA*, his after compensation income would equal $Y^0 + WTA^C$. This measure of *WTA* for a reduction in the quantity of wildlife-related amenities from Q^0 to Q^-, which we shall denote by the abbreviated notation WTA^C, was derived from a total value curve passing through the individual's initial state at Q^0, Y^0 (fig. 2).

However, there is another value measure sometimes used to estimate the individual wildlife amenity user's loss: the amount of money he would be willing to pay to avoid a reduction in the provision of wildlife amenities. What kind of value measure is *WTP* to avoid a less preferred situation? It assumes the individual must accept the less preferred situation, or pay to avoid it. Thus, the reference level of welfare is not the initial situation, but the proposed (or subsequent, in Hicksian terminology) welfare level. So, this second measure of the individual's welfare loss can be

$$(1) \qquad U = U(Q,Y).$$

The individual is thus at the origin (figure 1), which defines his level of welfare in the "without project" situation. Examine the axes. To the right of the origin, the level of provision of Q to the individual increases; to the left of the origin, it decreases. From the origin, a movement up the income axis indicates a decrease in income, while a movement down the vertical axis indicates an increase in income. The total value (TV) curve, or bid curve (Bradford), is of positive slope, given that the service is a commodity and the individual is not satiated in the range under consideration. For decreases in Q, the TV curve lies in the southwest quadrant; for increases in Q, it lies in the northeast quadrant. If it is possible to define the quantity of the service in unidimensional, cardinal terms, the assumption of diminishing rates of commodity substitution is sufficient to ensure the curvature shown. Alternatively, if "quantity" is multidimensional, or if it cannot be defined accurately in cardinal terms, no a priori assumption can be made concerning the curvature of the TV curve (Bradford).

The TV curve is an indifference curve, passing through the individual's initial state. That is,

$$(2) \quad U(Q,Y) = U(Q^-, Y^+) = U(Q^+, Y^-).$$

Starting at the origin, $Y^0 - Y^-$ is the individual's willingness to pay (WTP) to obtain an increment in the level of provision of the service from Q^0 to Q^+. Willingness to accept (WTA), i.e., $Y^+ - Y^0$, is the amount of money

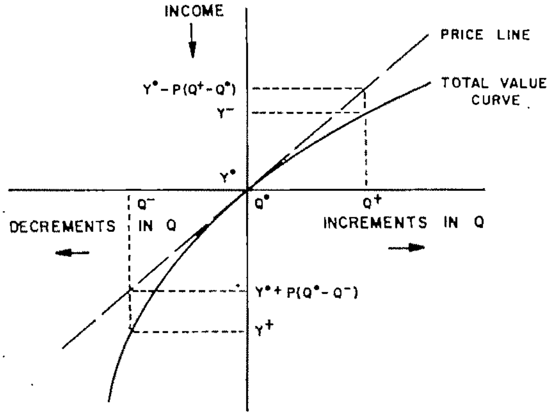

Figure 1. The total value curve for increments and decrements in the level of provision of a service, Q, for an individual who initially enjoys the level Q^0 and the income Y^0

which would induce the individual to accept voluntarily a decrease in the level of provision of the service from Q^0 to Q^-. Thus, WTP is the total value to the individual of an increment from Q^0 to Q^+; WTA is the total value to the individual of a decrement from Q^0 to Q^-. Restating equation (2),

$$(3) \quad U(Q^0, Y^0) = U(Q^-, Y^0 + WTA) = U(Q^+, Y^0 - WTP).$$

WTA and WTP bear the following relationship to the traditional market indicators of value. If $Q^+ - Q^0$ is a one-unit increment in Q, WTP is equal to the buyer's best offer for that increment. If $Q^0 - Q^-$ is a one-unit decrement, WTA is equal to the seller's reservation price for that decrement. If a market existed in which the individual could purchase the increment $Q^+ - Q^0$ for some amount less than his WTP, he would proceed with the purchase and enjoy a gain in trade. Likewise, if a market existed in which he could sell the decrement $Q^0 - Q^-$ for some amount more than WTA, he would proceed with the sale and again enjoy a gain from the transaction. If an increment would cost the individual more than his WTP, and a decrement would net the individual less than his WTA, he would eschew all trade in Q and remain at his initial situation.

WTP, *WTA*, and Consumer's Surplus

Following Mishan (1971, 1976), we argue that consumer's surplus is the appropriate measure of value in benefit-cost analysis; that consumer's surplus is correctly defined by the Hicksian measures, rather than the Marshallian measure; and that, unless a project or program is proposed primarily for the purpose of redistribution, the potential Pareto-improvement is the proper criterion for benefit-cost analysis and, therefore, Hicksian compensating measures are the proper measures of value. However, depending on the applied benefit-cost problem at hand, available value data may be in the form of market prices, Marshallian consumer's surplus, Hicksian compensating measures of consumer's surplus, WTP, or WTA. Our purposes in this section are to develop the relationships between these measures; to show that, in any particular benefit-cost situation, the proper measure of value can be identified on the basis of theoretical considerations; and to show that empirical estimates of the theoretically correct measure of value

Valuing Increments and Decrements in Natural Resource Service Flows

David S. Brookshire, Alan Randall, and John R. Stoll

A general model for valuation of changes in natural resource service flows, entirely consistent with Hicksian concepts of consumer surplus, is developed. It is a total value model, applicable to all classes of goods: divisible and indivisible in production, divisible and indivisible in consumption, exclusive and nonexclusive. The standard result of partial equilibrium microeconomics—price is equal to value at the margin—may be derived as a special case from this model. An empirical application involving the valuation of changes in the provision of wildlife-related amenities is presented.

Key words: consumer's surplus, natural resources, valuation, wildlife.

In the course of his work, the benefit-cost analyst frequently encounters situations in which a proposed program or project would divert natural resources from their current use to some, quite different, alternative. In keeping with the "with and without" principle, he must determine "without project" benefits, which are equal to the net present value of the stream of services that would be provided by the natural resource in its current use over the life of the proposed project. For example, projects are often proposed which would drain wetlands, fill coastal marshlands for housing or resort developments, dam free-flowing streams, inundate canyons, or divert wildlife habitat for agricultural, forestry, or mineral extraction purposes. These few examples suggest that the flow of goods, services, and amenities which must be valued to determine "without project" benefits is often complex. The natural resource often provides flows of goods, services, and amenities quite diverse in physical terms. In economic terms, too, the diversity of goods, services, and amenities produced may be awesome. There may be goods that are divisible, lumpy, or indivisible in production; divisible, congestible, or nonrival in consumption; and exclusive or nonexclusive. "With project" benefits are more likely to involve marginal increments in the supply of undifferentiated goods—e.g., agricultural commodities, electricity, and slack-water recreation—but may also include complex goods.

We propose a general conceptual model for the valuation of natural resource service flows. The model focuses on total value and, at the outset, would seem to represent a radical departure from the partial equilibrium, marginal microeconomics commonly applied in benefit-cost analysis. However, the model generates, as a special and limiting case, the traditional results of marginal analysis; and, in so doing, defines the appropriate role for marginal analysis in the benefit-cost framework.

The Total Value of Changes in the Level of Provision of a Service

Consider an individual who currently enjoys some specified level, Q, a service. In addition, he enjoys a given quantity of the Hicksian "all other goods" numeraire, Y, which for convenience is called income. Thus, his level of utility is always dependent upon his income and the quantity of the particular service upon which we focus, i.e.,

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Silage for Finishing Beef Cattle." *J. Animal Sci.* 42(1976):549–52.

Sonka, Steven T., Earl O. Heady, and P. Fred Dahm. "Estimation of Gain Isoquants and a Decision Model Application for Swine Production." *Amer. J. Agr. Econ.* 58(1976):466–74.

concave region. If time and grade are ignored, rations within a concave region would not be optimal. In general, for *ad libitum* feeding, as the energy concentration of the rations increases, the time required to achieve a given weight level declines. Thus, depending on the relative prices of roughage, concentrate, and time, either a high concentrate ration which contains a minimal amount of roughage to prevent rumen dysfunction, or a ration high in roughage, such as full corn silage, would be optimal.[3]

Roughage is bulky and relatively more difficult to transport, store, and feed than grains. Thus, producers who purchase feedstuffs might be expected to feed high concentrate rations. On the other hand, a corn producer who has silage production and storage facilities may feed a full corn silage ration. A full corn silage ration would yield more pounds of beef per acre. However, corn silage reduces soil cover, removes more nutrients, and increases the potential for erosion losses relative to corn grain.

Additional research is needed in several areas. For example, the NE_g of the soilage study (ignoring the full soilage ration) ranged from 0.84 to 1.23 Mcal./kg. and for the corn silage study from 0.99 to 1.24 Mcal./kg.[4] Experiments extending over a wider range of energy concentration could provide more information on the turning points between concave or linear and convex regions. Because of the nature of the function, six rations may be insufficient to detect accurately turning points. Work also is needed to determine the impact of nonnutrient additives and implants across rations. Finally, the impact of restricting intake should be explored.

We cannot conclude that a concave or linear region exists in the roughage-concentrate isoquant for all types of roughage and concentrates. Also, it is not entirely certain why the derived isoquants have the shape shown. These and other issues remain to be settled.

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[3] Carcass quality grades and yield grades were not statistically significantly different among the corn silage rations. Steers from all pens consistently graded low choice to high good across years and rations. Thus, the output can be assumed to be homogenous across rations for the corn silage experiment.

[4] Many producers feed rations that exceed the energy concentration of those fed in either experiment. For example, an 85% corn grain-15% corn silage ration has an estimated NE_g = 1.41 Mcal./kg.

References

Brokken, R. F., T. M. Hammonds, D. A. Dinius, and J. Valpey. "Framework for Economic Analysis of Grain versus Harvested Roughage for Feedlot Cattle." *Amer. J. Agr. Econ.* 58(1976):245–58.

Brokken, R. F. "The Case of a Queer Isoquant: Increasing Marginal Rates of Substitution of Grain for Roughage in Cattle Finishing." *W.J. Agr. Econ.* 1(1977a):221–24.

———. "Some New Perspectives on Trade-offs between Grain and Roughage in Cattle Finishing." *California Feeders Day 1977*, pp. 15–28. Dep. Animal Sci., University of California, 1977b.

Burt, Oscar R. "On the Statistical Estimation of Isoquants and Their Role in Livestock Production Decisions." *Amer. J. Agr. Econ.* 60(1978):518–23.

Byers, Floyd M., J. K. Matsushima, and D. E. Johnson. "The Significance of Associative Effects of Feeds on Corn Silage and Corn Grain Energy Values." *Beef Nutrition Res.*, pp. 18–21. Dep. Animal Sci., Colorado State University, 1975.

Dahm, Fred, Earl O. Heady, and Steven T. Sonka. "Estimation and Application of a Production Function in Decision Rules for Swine Producers." *Can. J. Agr. Econ.* 24(1976):1–16.

Dillon, John L. *The Analysis of Response in Crop and Livestock Production*, 2nd ed. Elmsford, N.Y.: Pergamon Press, 1977.

Fuller, Wayne A. "Grafted Polynomials as Approximating Functions." *Aust. J. Agr. Econ.* 24(1969):35–45.

———. *Introduction to Statistical Time Series*. New York: John Wiley & Sons, 1976.

———. "Some Properties of a Modification of the Limited Information Estimator." *Econometrica* 45 (1977):939–53.

Goodrich, R. D., D. W. Crawford, M. L. Thonney, and J. C. Meiske. "Influence of Corn Silage Level on the Performance and Economic Returns of Steers Calves." *1974 Minnesota Cattle Feeders Report*, pp. 14–19. Dep. Animal Sci., University of Minnesota, 1974.

Heady, Earl O., and John L. Dillon. *Agricultural Production Functions*. Ames: Iowa State University Press, 1961.

Heady, Earl O., Glenn P. Roehrkasse, Walter Woods, J. M. Scholl, and Wayne Fuller. "Experimental Production and Profit Functions for Beef Steers." *Can. J. Agr. Econ.* 11(1963):29–40.

Johnston, J. *Econometric Methods*, 2nd ed. New York: McGraw-Hill Book Co., 1972.

Melton, Bryan E., Earl O. Heady, Richard L. Willham, and M. Peter Hoffman. "The Impact of Alternative Objectives on Feedlot Rations for Beef Steers." *Amer. J. Agr. Econ.* 60(1978):683–88.

Morrison, Frank B. *Feeds and Feeding*, 22nd ed. Ithaca, N.Y.: Morrison Publishing Co., 1956.

National Academy of Sciences. *Nutrient Requirements of Beef Cattle*, 5th rev. ed. Washington, D.C.: National Research Council, 1976.

Perry, T. W., and W. M. Beeson. "Ratios of Corn to Corn

Table 4. Corn Silage-Concentrate Production Functions Estimated in Polar Coordinates with Weight Gain from 320 kg. as the Dependent Variable

	Explanatory Variables												
Equation	d	θd	$\theta^2 d$	$\theta^3 d$	d^2	θd^2	$\theta^2 d^2$	$\theta^3 d^2$	$D1d$	$D2d$	R^2	MSE	df
Ad Libitum Intake													
4.1	0.1517	0.1101	−0.0697		−0.000020	−0.000015	0.000009		−0.0090	−0.0257	0.82	20.17	94
	(13.40)[a]	(2.93)	(2.97)		(2.70)	(0.51)	(0.52)		(1.76)	(5.30)			
4.2	0.1580	0.0335	0.0630	−0.0565	−0.000023	0.000011	−0.000035	0.000019	−0.0092	−0.0259	0.83	20.00	92
	(13.01)	(0.40)	(0.47)	(1.01)	(2.88)	(0.17)	(0.34)	(0.45)	(1.80)	(5.35)			
Restricted Intake													
4.3	0.1549	0.1492	−0.0850		−0.000016	−0.000037	0.000015		−0.0154	−0.0387	0.76	26.59	94
	(10.97)	(2.96)	(2.68)		(1.69)	(0.85)	(0.54)		(2.29)	(6.05)			

[a] Numbers in parentheses are t-values (absolute value).

rived from equation (4.1) are graphed in figure 4. They are concave over a wide range of rations. They are not progressively tipped away from the corn silage axis. Thus, for this particular study, in which the range of rations in terms of energy concentration is relatively small, and the range of gain considered is also relatively small, tipping is not evident. Of course, tipping would be easier to detect if both the range of gain and the range of energy concentration were increased.

Corn Silage (Restricted Intake) Estimates

The directly estimated 160-kilogram-restricted intake gain isoquant is reported as equation (3.2) in table 3. It is graphed in figure 5. This estimated isoquant also has a nonconvex range.

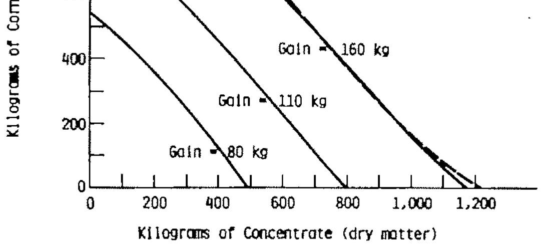

Figure 5. Corn silage restricted intake isoquants—direct estimate and production function estimates

The second degree polynomial production function estimate, equation (4.3), resulted in a lower MSE than the third and fourth degree functional forms. As with equation (4.1), the estimated regression coefficients on θd^2 and $\theta^2 d^2$ are not statistically significantly different from zero at the 0.10 level of probability. However, the other coefficients are significant at this level. Three isoquants derived from equation (4.3) are graphed in figure 5. They are also concave over a wide range of rations.

Equations (3.2) and (4.3) both exhibit sigmoid isoquants. Unlike Brokken's sigmoid isoquants, the corn silage isoquants show a convex range in the high concentrate region. The ration which is devoid of hay or silage is probably not a good ration for physiological reasons.

Even though the restricted intake scenario might be expected to increase the time on feed and, thus, the energy required for maintenance and, thus, the total feed required, the restricted intake isoquants lie below the corresponding *ad libitum* isoquants across all rations. This suggests that if time is ignored, *ad libitum* feeding is inefficient.[2]

Implications and Conclusions

The isoquants and production functions estimated from the data of the two experiments suggest that we cannot reject the hypothesis that the overall beef gain roughage-concentrate isoquant may have a linear or

[2] Because the marginal product of feed is zero beyond stomach capacity, Dillon (p. 99) has suggested that *ad libitum* feeding may not be optimal.

$$(8)\quad A = a_0 + a_1B + a_2B^2 + DO + D1B,$$

where $DO = b_0 - a_0 + A_0 - a_1B_0 + a_2B_0^2$ and $D1 = -2a_2B_0$.

A similar procedure can be followed to adjust for trial 3 differences. The regression equation used to estimate the quadratic gain isoquants for the three trials pooled is

$$(9)\quad \hat{A} = a_0 + a_1B + a_2B^2 + a_3D1 + a_4D1B + a_5D2 + a_6D2B,$$

where A and B are interpolated quantities of concentrate and corn silage required for the specified weight gain, $D1 = 1$ for trial 2, 0 otherwise, and $D2 = 1$ for trial 3, 0 otherwise (Dahm, Heady, Sonka).

For production functions estimated in polar coordinates, dummy "distance" variables can be used to account for differences among trials. Because rations, in terms of proportions of corn silage and concentrate in the feed, were fixed for all trials, the measure of "angles" does not vary among trials. The following example illustrates the type of dummy variables used and the form of a second degree function:

$$(10)\quad W = (a_0 + a_1\theta + a_2\theta^2)d + (a_3 + a_4\theta + a_5\theta^2)d^2 + (a_6D1 + a_7D2)d + U,$$

where $D1 = 1$ for trial 2, 0 otherwise, and $D2 = 1$ for trial 3, 0 otherwise. The variable θ is not used without interaction with d since this would imply a variable intercept term.

Corn Silage (*Ad Libitum* Intake) Estimates

The dummy variable techniques were used to adjust starting weights to 320 kilograms. Cubic, quadratic, and linear functional forms were fit. The cubic functional form reported in table 3 resulted in the lowest MSE. It reflects a gain of 160 kilograms from a starting weight of 320 kilograms.

Perhaps as a result of the limited number of observations, most of the estimated coefficients of equation (3.1) are not statistically significant. It is graphed in figure 4. The isoquant is concave with a convex tail near the concentrate axis.

Production function estimates were obtained in polar coordinates. Polynomial functions of the second, third, and fourth degree in angle θ were estimated. The fourth degree function did not reduce MSE. The second and third degree functions are reported in table 4. All estimated coefficients of equation (4.1), except for those on θd^2 and $\theta^2 d^2$, are significant at the 0.10 level of probability. However, only the coefficients on d, d^2, and the dummies are significant at the 0.10 level for equation (4.2). The 80-kg., 120-kg., and 160-kg. isoquants de-

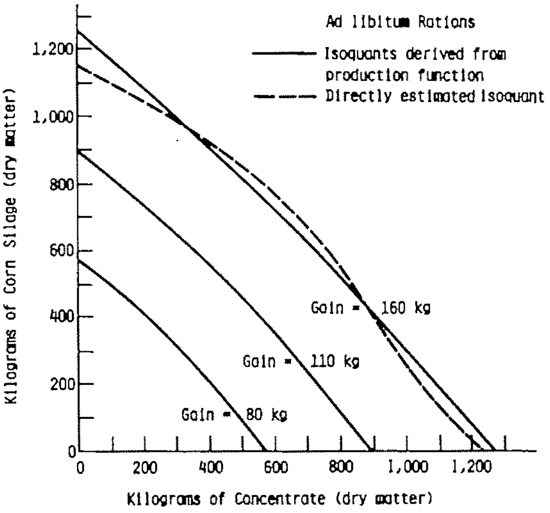

Figure 4. Corn silage *ad libitum* intake isoquants—direct estimate and production function estimates

Table 3. Corn Silage-Concentrate Directly Estimated Isoquants with Concentrate as the Dependent Variable (320 to 480 kg.)

	Explanatory Variables												
Equation	Intercept	B^{*a}	B^{2*}	B^3	$D1$	$D1B^*$	$D1B^{2*}$	$D2$	$D2B^*$	$D2B^{2*}$	R^2	MSE	df
Ad Libitum Intake													
3.1	1,228.7	−1.0736	0.0010	−0.0000009	−482.34	−0.2509	0.0004	−420.00	−0.3128	0.0001	0.99	3,272.0	8
	(18.37)[b]	(1.57)	(0.74)	(1.21)	(5.96)	(0.54)	(0.80)	(4.92)	(0.53)	(0.23)			
Restricted Intake													
3.2	1,226.9	−1.4659	0.0012	−0.0000008	−490.91	0.1307	0.0001	−324.22	−0.5056	0.0006	0.99	3,917.0	8
	(16.99)	(2.26)	(0.92)	(0.93)	(5.34)	(0.25)	(0.14)	(3.55)	(0.95)	(1.20)			

[a] The IV procedure was used to obtain estimates of B, B^2, and B^3 which are independent of concentrate consumption (B is corn silage consumption).
[b] Numbers in parentheses are t-values (absolute value).

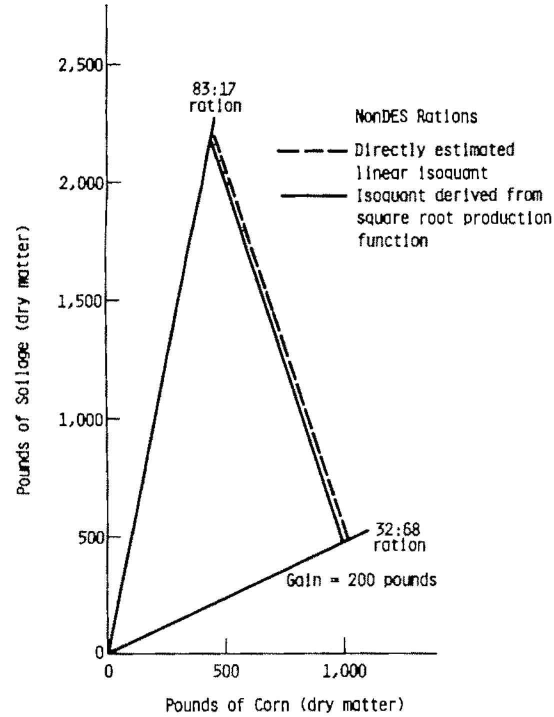

Figure 3. Soilage without DES isoquant—direct estimate versus production function estimate

tive. Also, the two isoquants are more divergent for the higher roughage rations. Perhaps, the impact of DES varies across rations. Because the data were collected on two different farms, soilage quality and weather could not be fixed across farms. Thus, the difference in the estimates may be due to factors other than the DES.

The soilage experiment was limited in time to the length of the growing season. Hence, not all of the steers, especially those receiving the full soilage ration, had equal opportunity to gain equivalent amounts. The steers of the corn silage experiment were permitted to gain equivalent weights, and, consequently, did not face this problem. Because one of the rations of the corn silage experiment did not contain any roughage, we might expect a sigmoid isoquant with a convex tail on the high concentrate end.

Functional Forms

Conventional functional forms for production function estimation, such as Cobb-Douglas, quadratic, and square root, do not permit sigmoid isoquants. The grafted polynomial approach developed by Fuller (1969) and applied to the beef gain problem by Melton et al. can be used to permit sigmoid isoquants. However, the grafting technique requires some method for estimating a join line. Production functions estimated in polar coordinates provide a more general approach in that functional forms may be chosen which place fewer restrictions on derived quantities. They will permit sigmoid isoquants as well as tipping. Thus, the corn silage production functions were estimated in polar coordinates.

Any point in a rectangular coordinate system can be described as being some distance, d, from the origin. Also, a line from the point to the origin forms an angle, θ, with the horizontal axis. The points of a polar coordinate system are described in this manner. Because the corn silage experiment can be described with only two variable inputs, the data can be transformed conveniently into polar coordinates in the following manner. Let

$$W = f(d,\theta), \tag{5}$$

where W is kilograms of weight gain per steer for the period; d is $(A^2 + B^2)^{\frac{1}{2}}$; θ is tan^{-1} (A/B); A is kilograms DM of concentrate; and B is kilograms DM of corn silage.

Starting Weight Adjustments

The starting weights of the steers in the corn silage study differed across trials. Thus, adjustments were necessary to account for trial-to-trial differences. Dummy variables were used to accommodate different starting weights for the directly estimated isoquants. The actual starting weights were 320 kg., 370 kg., and 395 kg. for trials 1, 2, and 3, respectively. If we let the 160 kg. gain isoquant for trial 1 be

$$A = a_0 + a_1B + a_2B^2; \tag{6}$$

and the 110 kg. gain isoquant for trial 2 be

$$A = b_0 + b_1B + b_2B^2, \tag{7}$$

then, by restricting a_1 to equal b_1 and a_2 to equal b_2, trial 2 can be represented as

$$(A - A_0) = b_0 + a_1(B - B_0) + a_2(B - B_0)^2,$$

where A_0 and B_0 are the unknown quantities of concentrate and corn silage utilized by the steers of trial 1 to achieve the initial 50 kilograms of gain. This equation can be written as

Table 2. Soilage-Corn Grain Production Function Estimates with Weight Gain from 840 Pounds as the Dependent Variable

Equation	Explanatory Variables										
	Intercept	C^a	S	$C^{½}$	$S^{½}$	$(CS)^{½}$	$D1$	$D2$	R^2	MSE	df
With DES											
2.1	12.6	0.1562	0.0779	1.6882	0.7390	−0.0938	−31.8	36.2	0.95	225.07	113
	(0.83)[b]	(6.69)	(3.11)	(1.52)	(0.59)	(2.40)	(5.41)	(6.48)			
2.2	18.8	0.1535	0.0900	2.0102		−0.0968	−31.2	36.7	0.95	224.43	114
	(1.71)	(6.65)	(7.00)	(2.09)		(2.54)	(5.36)	(6.62)			
IV Estimate											
2.3[c]	17.2	0.1368	0.0789	1.6412		−0.0558	−30.4	37.9	0.95	229.64	114
	(1.20)	(5.71)	(5.21)	(1.25)		(1.20)	(5.08)	(6.72)			
Without DES											
2.4	44.3	0.0888	0.0357	1.7560	0.2980	−0.0050	−39.6	12.3	0.96	190.06	113
	(3.54)	(5.34)	(2.61)	(2.14)	(0.38)	(0.21)	(9.50)	(3.81)			

[a] C and S refer to quantities (dry matter) of corn and soilage consumption; $D1$ and $D2$ are dummy variables for years and equal 1 for years 1 and 2, respectively, and zero otherwise.
[b] Numbers in parentheses are t-values (absolute value).
[c] The IV procedure was used to estimate this production function.

tion (2.3) is graphed in figure 2. It is concave to the origin over the data range. Thus, the directly estimated isoquant, equation (1.1), the "traditional" production function estimates, equations (2.1) and (2.2), and the IV production function estimate, equation (2.3), all yield isoquants that are slightly concave to the origin over the data range. We feel that we can conclude that the beef gain soilage-corn grain isoquant derived from the soilage with DES experiment has a nonconvex range. Further, the full soilage ration, which very likely restricted energy intake, masked the nonconvex range in the previous analysis of the data.

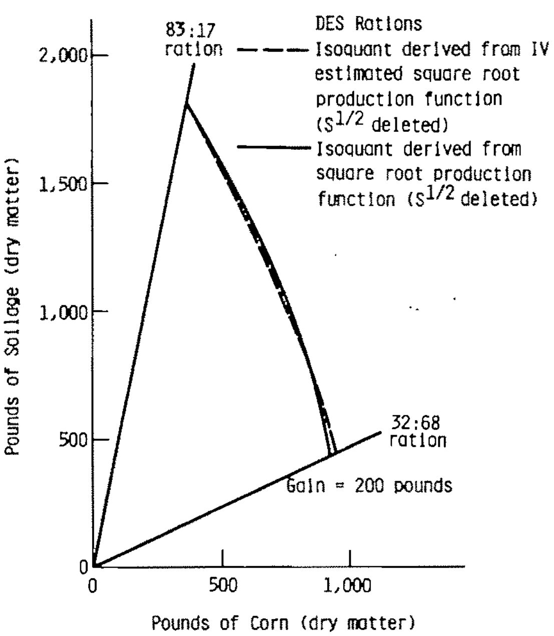

Figure 2. Soilage with DES isoquant—production function estimate versus instrumental variables-production function estimate

Soilage (without DES) Estimates

Data from the soilage without DES experiment also were reanalyzed. The directly estimated 200-pound gain quadratic isoquant is reported in table 1. The graph of equation (1.2) is slightly concave to the origin. But, the coefficient of S^2 is of questionable significance. Thus, the square term was dropped. Equation (1.3), the linear fit, resulted in a lower MSE than the quadratic fit. It is graphed in figure 3.

The production function for the soilage without DES experiment is reported in table 2. All estimated coefficients for equation (2.4) are statistically significantly different from zero at the 0.05 level of probability except for the square root of S and the interaction term. The 200-pound isoquant derived from equation (2.4) is graphed in figure 3. It is very slightly convex to the origin.

The isoquant estimates obtained from the data of the pens which did not receive DES are more nearly linear than those estimated from the DES data. A linear isoquant has the same ration and cost implications as a concave isoquant. Isoquants derived from the nonDES data lie above those derived from the DES data for all rations. This finding is consistent with the popularity of using the hormone addi-

was used to provide estimates of soilage consumption that are independent of the estimates of the quantity of corn consumed such that isoquants could be estimated directly. Linear, quadratic, and cubic functional forms were used to fit the isoquants. The quadratic estimate resulted in the lowest mean square error (MSE). It is reported in table 1. The negative coefficient on the square term for equation (1.1) is statistically significant at the 0.01 level of probability. The isoquant is graphed in figure 1. It is concave to the origin.

Gain production functions also were estimated from the five rations of the soilage experiment which were expected to fall within the concave range of the overall isoquant. Quadratic and square root functional forms were used. The square root estimate resulted in the smallest MSE. It is reported in table 2.[1] The 200-pound isoquant derived from equation (2.1) is graphed in figure 1. It is concave to the origin.

Because the square root term on S in equation (2.1) is of questionable significance, it was dropped and equation (2.2) was estimated. The 200-pound isoquant derived from equation (2.2) is graphed in figure 2. It is also concave to the origin.

As noted previously, if we do not "trust" the results of the F-test regarding OLS bias, and if instruments are available, the full production function can be estimated with the IV procedure. Thus, because isoquants derived from the production functions, equation (2.1) and (2.2), are concave, and because this is the

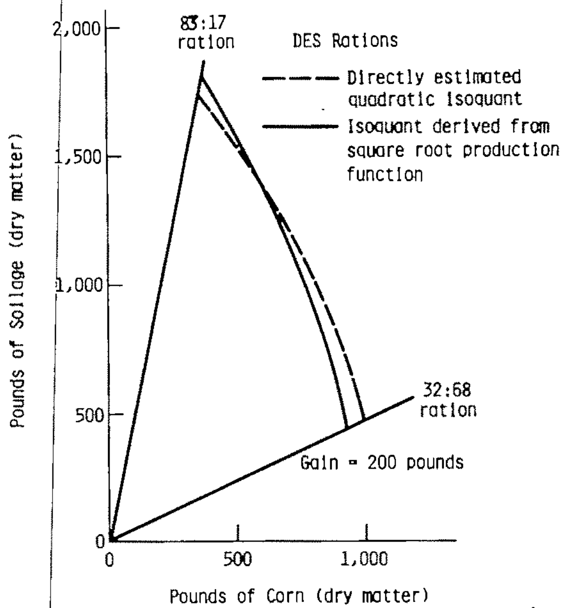

Figure 1. Soilage with DES isoquant—direct estimate versus production function estimate

crucial issue, we utilized the IV procedure to estimate the full production function for the soilage with DES data set.

The procedure is similar to that used in the direct estimation of isoquants. Following Fuller (1976, p. 224), we used time on feed, proportion of roughage in the ration, and the interaction of time with ration as instruments on which to regress C and S. Predicted values from these regressions along with their powers were used in second round regressions to prepare "independent variables" for the production function estimate. The resulting estimate is reported as equation (2.3) in table 2.

The 200-pound isoquant derived from equa-

[1] In the original analysis, a quadratic function was fit. It did not contain an intercept term or dummy variables for the three trials. However, a temperature variable was included (Heady et al.). Unfortunately, the temperature data were not located.

Table 1. Soilage-Corn Grain Directly Estimated Isoquants with Corn Grain as the Dependent Variable (840 to 1,040 Pounds)

	Explanatory Variables							
Equation	Intercept	S^{*a}	S^{2a}	$D1$	$D2$	R^2	MSE	df
With DES								
1.1	1,013.3	0.0346	−0.00025	334.1	−249.3	.95	4,277.3	14
	(12.14)[b]	(0.24)	(4.07)	(8.47)	(7.08)			
Without DES								
1.2	1,070.3	−0.2687	−0.000019	373.5	−109.6	.74	18,020.8	15
	(11.10)	(2.73)	(0.71)	(4.36)	(1.53)			
1.3	1,109.7	−0.3286		368.1	−109.9	.75	16,082.8	16
	(14.94)	(6.94)		(4.57)	(1.62)			

[a] The IV procedure was used to obtain estimates of S and S^2 which are independent of corn grain consumption (S is pounds dry matter of soilage; $D1$ and $D2$ are dummy variables for years and equal 1 for years 1 and 2, respectively, and zero otherwise).
[b] Numbers in parentheses are t-values (absolute value).

When animals are fed *ad libitum,* they, and not the research workers, control the rate of feed intake. Thus, the recorded feed intake quantities may contain a stochastic component which may not be independent of the equation error. Fuller (1977) has developed a statistical test to determine if OLS estimates will be nearly unbiased. The F-test was applied to the data of each trial. The null hypothesis that OLS estimators would be nearly unbiased was not rejected at the 0.05 level of probability for any of the data sets. Thus, we could proceed under the assumption that OLS is appropriate.

Alternatively, if the results of the F-test were not satisfactory, and if variables which can be used as instruments are available, the instrumental variables (IV) procedure can be used to estimate the production function (Fuller 1976).

The IV procedure can be used to obtain consistent estimates of the regression coefficients for both situations involving stochastic regressors as well as situations involving errors in variables. However, the stochastic nature of feed consumption by the animals is probably of greater importance for the present analysis than any "measurement error" associated with the regressors. Hence, the gain production function model is essentially a regression model with stochastic independent variables which may be correlated with the equation error.

Direct Estimation of Isoquants

Sonka, Heady, and Dahm used the IV procedure to estimate directly swine gain isoquants. They used ration protein percentage as the instrument for estimating the quantity of supplement consumed. The isoquant was estimated by regressing recorded values of corn consumption on predicted values of supplement consumption. Burt suggested that the isoquant estimate was not needed because the isoquant could be determined from the initial estimate. This would hold if a theoretical relationship exists between the random independent variables and the instruments and if the relationship is properly specified by the functional form. This requirement is not necessary for the IV procedure.

Our objective is to estimate directly beef gain roughage-concentrate isoquants. The equation to be estimated is

$$C = f(S,\Psi) + U, \tag{1}$$

where C and S are quantities of the two feeds, f is the functional form, Ψ a set of parameters, and U the residual error term. Neither C nor S satisfy the classical regression model assumptions with respect to independent variables. Thus, OLS estimates may be seriously biased as a result of the correlation between U and S. The IV procedure defined by Fuller (1976, p. 220) can be used to obtain consistent estimates if information is available on fixed variables which are correlated with the "independent variables" and not correlated with the random error term of the model. For both experiments, treatments were fed along fixed ration lines. In other words, the percentage of roughage (and concentrate) fed to each pen was fixed experimentally. This variable, call it N, can be used to build instrumental variables to estimate equation (1). In addition, the vector of "ones," along with the dummy variables, call them M, can also be used as instruments.

Powers of S can be used in equation (1) to permit a nonlinear isoquant. Thus, we could estimate

$$S^*,\ S^{2*} = G(N,M), \tag{2}$$

and use the predicted values of S^* and S^{2*} in equation (1). However, we arbitrarily selected the following alternative procedure. First we estimate

$$\hat{S} = G(N,M), \tag{3}$$

and use the predicted values and powers of predicted values from this estimate, call them Z, in "second round" estimates.

$$S^*,\ S^{2*} = h(Z,M). \tag{4}$$

Predicted values from these estimates are used to estimate directly the isoquant, equation (1).

We note that the residuals from equations (2), (3), and (4) "may be a sum of random and fixed components" (Fuller 1976, p. 221), in which case it would be inappropriate to solve them for the isoquant. The appropriate residuals for the isoquant estimate, equation (1), should be based on the recorded values of the "independent" variable. Thus, they were directly computed and used to calculate the estimated variance and t-values.

Soilage (with DES) Estimates

The soilage data were interpolated to a weight gain level of 200 pounds. The IV procedure

distort a slightly concave region and result in an overall convex isoquant as Brokken et al. suggest. Thus, the data were reanalyzed.

Data indicated that the rates of gain were slower on the full soilage ration such that half of the pens receiving that ration did not gain 200 pounds during the pasture season. Therefore, the full soilage ration (100:0) was dropped from the data set, and estimates were obtained from the remaining five rations. The estimated NE_g for these five rations ranged from 0.84 to 1.23 Mcal./kg. Based on the work of Brokken et al., these five rations would be expected to fall in the concave region of the isoquant.

Corn Silage Experiment

The corn silage feeding trial was conducted over a three-year period. Yearling crossbred steers, primarily of Angus and Hereford breeding, were placed on feed in the fall and slaughtered in the following spring. A total of 278 cattle were fed: 96 in the first and third years and 86 in the second.

Six rations were fed. Rations were composed of whole plant corn silage, whole shelled corn grain, dehydrated alfalfa pellets, and a soybean meal base supplement fortified with vitamins and minerals. Corn grain and alfalfa pellets were fed in a constant ratio of two parts corn grain to one part alfalfa pellets on an as-fed basis. This fixed proportion mixture is referred to as concentrate. The DM ratios of corn silage to concentrate, ignoring the supplement, were approximately: 100:0, 82:18, 63:37, 44:56, 23:77, and 0:100. The 100:0 ration was composed entirely of corn silage and supplement. Corn grain, alfalfa pellets, and supplement made up the 0:100 ration. All of the animals were implanted with 30 milligrams of DES immediately prior to the feeding trial. The supplement was fed at a constant rate of about 0.8 kilograms per animal per day.

In each year, twelve pens of cattle were fed. Six pens were fed a constant quantity of metabolizable energy per day. Hence, their intake was restricted. The other six pens were fed *ad libitum*.

The energy concentration, as measured by NE_g, ranged from 0.99 Mcal./kg. for the full corn silage ration, to 1.22 Mcal./kg. for the full concentrate ration (National Academy of Sciences). Based solely on the criterion of energy concentration, these rations would be expected to fall in the concave region of the proposed sigmoid isoquant. However, the National Research Council suggests that a minimal amount of roughage generally is necessary to prevent rumen dysfunction. Morrison also recognized the need for some roughage in the diet to prevent animals from being thrown off feed. Thus, the full concentrate ration might fall outside the proposed concave region.

Estimation Procedures

Traditionally, gain isoquants have been derived from production functions estimated by regressing cumulative weight gain on cumulative feed intake. For example, see Heady and Dillon. Several statistical problems are generally encountered. One potential problem is autocorrelated residuals.

Autocorrelation

Because successive measurements are made on the same experimental units over time, ordinary least squares (OLS) residuals associated with these measurements may be correlated. Several methods have been devised to correct for autocorrelation. If the number of experimental units per trial is relatively large, the full covariance matrix of the disturbance terms can be estimated. For example, see Dahm, Heady, and Sonka. Unfortunately, the number of experimental units, pens, per trial was limited to eight in the soilage study and six in the corn silage study.

A more common method of correcting for autocorrelation is to make an assumption about the autoregressive nature of the residual terms. Animals with low (high) rates of gain in one time period generally compensate with high (low) rates of gain in the next period. The effects of these compensatory gains generally are expected to dissipate in ten to fourteen days. Because the measurement periods for the experiments analyzed ranged from twenty-one to twenty-eight days, a first-order autoregressive scheme seems to be a reasonable assumption (Heady et al.). Transformation matrices were estimated for each trial and the data were transformed for production function estimation (Johnston, p. 260).

Stochastic Regressors

An additional statistical problem may be encountered in production function estimation.

Empirical Investigations of Beef Gain Roughage-Concentrate Substitution

Francis Epplin, Shashanka Bhide, and Earl O. Heady

The shape of the beef gain roughage-concentrate isoquant is examined. Data from two beef-feeding experiments designed to investigate response from alternative combinations of roughage and concentrate are utilized. Isoquants derived from estimated production functions are compared with directly estimated isoquants. The estimates indicate that the isoquant is not strictly convex to the origin. The nonconvex region is more pronounced in estimates obtained from data of steers fed diethylstilbestrol.

Key words: beef feeding, concentrate, instrumental variables, isoquant, roughage.

Several studies published during the last decade have suggested that the beef gain roughage-concentrate isoquant may not be strictly convex to the origin (Brokken et al.; Brokken 1977a, b; Byers, Matsushima, Johnson; Goodrich et al.; Perry and Beeson). In general, the studies suggest that a nonconvex region may exist over a range of rations extending from where the energy concentration is so low that gut fill restricts intake, to where roughage intake is so low (high energy concentration) that digestive problems result. In addition, Brokken's work suggests that successive isoquants tip away from the roughage axis such that the ability of roughage to compete economically with concentrate diminishes as animal weight increases. This tipping phenomenon, along with a nonconvex region in the isoquant, would explain the popularity of feeding high roughage rations to light animals, followed by a high concentrate ration at heavier weights.

Soilage Experiment

A study of soilage (fresh-chopped alfalfa-bromegrass) and corn grain substitution reported by Heady et al. shows isoquants which are convex to the origin. The isoquants were derived from a statistically estimated production function. Given the knowledge of the time, the convex isoquants were deemed acceptable. However, based on more recent findings, we might expect a concave region in the soilage-corn grain isoquant.

Hereford yearling steers weighing approximately 840 pounds were assigned randomly to one of two farms and one of six rations. Rations at one location included diethylstilbestrol (DES) (with DES), while those at the other location did not (without DES). The dry matter (DM) ratios of soilage to corn grain were approximately as follows: 100:0, 83:17, 70:30, 54:46, 41:59, and 32:68. The estimated net energy for gain (NE_g) in terms of megacalories per kilogram (Mcal./kg.) for the six rations was: 0.71, 0.84, 0.94, 1.06, 1.16, and 1.23 (National Academy of Sciences).

Based on Brokken's work, the energy concentration of the full soilage ration was so low that gut fill would restrict energy intake to something less than the physiological demand for energy. Thus, this ration would fall in the convex range of Brokken's proposed sigmoid isoquant (Brokken 1977a). However, the energy concentration of the other five rations was sufficiently high that the physiological demand for energy could be met prior to encountering the gut fill restriction. They would fall in the concave range of the proposed sigmoid isoquant. If the isoquant is sigmoid, a quadratic gain-production function estimate based on the six rations combined could give misleading results. The convex region might

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Ladd, George W., and Joseph E. Williams. "Application of Net Energy System and Bayesian Decision Theory for Determination of Cattle Rations and Rates of Gain." *J. Animal Sci.* 45(1977):1222–30.

Larson, John T. "Seasonality of the Cattle Market." Washington, D.C.: USDA ERS–468, 1971.

Malinvaud, E. "First Order Certainty Equivalence." *Econometrica* 37(1969):706–18.

National Research Council. *Nutrient Requirements of Beef Cattle*, 5th rev. ed. Washington, D.C.: National Academy of Sciences, 1976.

Nelson, Charles R. *Applied Time Series Analysis for Managerial Forecasting.* San Francisco: Holden Day, 1973.

Plaxico, James S., and James L. Jackson. "Beef Cattle Prices, Seasonal Movements and Price Differentials on the Oklahoma City Market." Oklahoma State University Agr. Exp. Sta. Bull. B-486, Feb. 1957.

Price, M. A., and R. T. Berg. "Grain-Finishing Beef Cows Culled from the Breeding Herd." *The 58th Annual Feeder's Day Report.* University of Alberta, Agriculture and Forestry Bull. 1979:53–6.

U.S. Department of Agriculture, Agricultural Marketing Service. *Official United States Standards for Grades of Carcass Beef.* Washington, D.C., 1975.

Wooten, R. A., C. B. Roubicek, J. A. Marchello, F. D. Dryden, and R. S. Swingle. "Realimentation of Cull Range Cows. 2 Changes in Carcass Traits." *J. Animal Sci.* 48(1979):823–30.

Yager, William A. "Marketing Cull Cows under Uncertainty." M.S. thesis, Montana State University, 1977.

ues was used. It was assumed that cows weighing less than 400 kg. would grade canner, cows weighing 400 to 447.5 kg. would grade utility, and cows weighing 450 kg. or more would grade commercial. These weights were believed to correspond to the body condition-slaughter grade designation of an English breed beef cow weighing about 450 kg. in "normal" range condition.

Ordinary least squares was used to estimate equation parameters for determining utility and canner prices from the commercial price. Data used were 197 observations of monthly average cow prices at Billings, Montana, for the period January 1960 through May 1976. The estimated equations are

$$P_{utility} = -1.011 + \underset{(11.74)}{1.038}P_{commercial},$$
$$R^2 = 0.986 \qquad SE = 0.708$$
$$P_{canner} = -1.1219 + \underset{(86.3)}{0.9703}P_{commercial}.$$
$$R^2 = 0.956 \qquad SE = 1.09$$

(Values in parentheses are t-values.) Thus, the expected immediate returns from decisions to sell cows and terminal values were calculated as (a) (weight) (−1.1219 + 0.9703 Price), for cows weighing less than 400 kg.; (b) (weight) (−1.011 + 1.038 Price), for cows weighing 400 to 447.5 kg.; and (c) (weight) (Price), for cows weighing 450 kg. or more.

Again, the resulting optimal decisions and expected returns from an optimal policy are as one might anticipate. It is, of course, the case that at any stage, the optimal decision and expected returns from an optimal policy for all states where cows would grade commercial will be the same as those presented above from the initial model. Again, remember that the returns pertain to the average yield within the grade; there would be price discounts for lower-than-average yields and price premiums for higher-than-average yields within the grade.

For cows that can be expected to change grade, expected returns for holding and feeding would be increased. This is particularly true of cows that would change from canner to utility grade, where the price differential is greatest. Expected net returns from an optimal policy for light cows in November and December was as high as \$55 under the grade change assumption compared to \$40 under the initial single price assumption. Holding and feeding is an optimal decision through later stages of the planning period, and in some cases the optimal decision is to feed for higher rates of gain. In fact, with the possibility of grade change, holding and feeding cows in the weight range 380 kg. to 395 kg. was the optimal decision in September and October for all prices considered. This is in contrast to the results of the other two solutions where the optimal decision for all states in September and October was sell immediately.

Concluding Remark

Under the single slaughter grade assumption, results indicate that marketing cull beef cows under an optimal policy which includes holding and feeding increases expected returns by \$20 to \$40 per head over selling immediately at early stages of the planning horizon, November and December. The increase amounts to 15% to 20% of the value of the cow when sold at the prices and weights considered in this study. As would be anticipated, expected net returns from an optimal policy decrease at succeeding stages until, ultimately, the optimal decision is to sell immediately, where the expected net return is equal to zero. Slaughter grade differences were incorporated into the analysis by assuming that a cow of specific weights would grade canner, utility, or commercial, and cow prices were adjusted to reflect grade-price differences. Expected net returns from marketing under an optimal policy increased to as much as \$55 per head for cows that would change grade while being held and fed.

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References

Box, George E. P., and Gwilym M. Jenkins. *Time Series Analysis: Forecasting and Control*, rev. ed. San Francisco: Holden Day, 1976.

Burt, Oscar R., and John R. Allison. "Farm Management Decisions with Dynamic Programming." *J. Farm Econ.* 45(1963):121–36.

Erich, Rollo L., Richard A. Glandt, and James S. St. Clair. "Net Returns to Producers for Cattle Sold at Selected Terminals and Wyoming Auction Markets, 1959–65." Wyoming Agr. Exp. Sta. Res. J. 24, Dec. 1868.

Foote, R. J., and Karl A. Fox. *Seasonal Variation: Methods of Measurement and Tests of Significance*. Washington, D.C.: USDA AMS Handbook No. 48, 1952.

are at most $10. For the stages September and October, the optimal decision was to sell cows immediately. This result is subject to the model restriction that cows must be sold by the end of October. It could be the case that if cows could be held for higher prices expected after November and pasture was considered as a decision alternative, the optimal decision, as part of an optimal policy with more than a one or two month horizon, would be different. A complete presentation of the optimal decision rules may be found in Yager.

Cost of Capital

For some states in the above results, expected net returns from holding and feeding a cull cow were quite small, less than $1.00. While this is an additional return above all costs, it suggests that optimal decisions would be sensitive to costs. To test sensitivity to the cost of capital and the risk-of-death losses, optimal decisions and expected returns from an optimal policy were obtained under the assumption that the combined effect of survival and the interest rate was .81025 annually, making $\delta = .9828$; this would imply an annual interest rate of 23% if there were no risk of death loss. Results are as might be anticipated. The expected net returns from an optimal policy are decreased to a range of $10 to $25 at early stages of the planning period compared to the previous $20 to $40 range. At later stages in the planning period, where expected net return was low, the optimal decision is more often sell immediately. On the other hand, the optimal decision at early stages of the planning period is in most cases the same as that obtained earlier. The most changes occur in March and April, where the optimal decisions were to hold and feed for various rates of gain in a majority of states, but under the higher discount factor the optimal decision is to sell most cows immediately.

Grade Changes

The price prediction model and results presented above are based on a single data series, commercial grade cow prices at the Billings, Montana, market, and the implicit assumption that all cows regardless of weight or body condition, are valued at the same per-unit, live-weight price. However, cull beef cows are not necessarily perfect substitutes for one another; there are usually per-unit live-weight price differences for cows of different slaughter grades. Slaughter cattle carcasses are evaluated for quality—". . . the palatability-indicating characteristics of the lean . . ." (USDA Agr. Mktg. Ser., p. 5)—and yield—". . . percent of trimmed, boneless, major retail cuts . . . derived from the carcass . . ." (USDA Agr. Mktg. Ser., p. 5). Quality is evaluated primarily by firmness and fullness of muscling and physical characteristics that are associated with age. Yield is primarily evaluated by amount of fat, ribeye area, and carcass weight.

It long has been believed that producers could affect only the grade of a slaughter cow by changing finish or fatness. Mature cows got heavier by getting fatter and *ceteris paribus*, a fatter cow graded higher. However, recent results show that while lipid comprises 50% of the carcass weight gain, fed cull beef cow carcasses were of higher quality than carcasses from cows slaughtered at culling (Wooten et al. and Price and Berg). The fed carcasses had higher marbling scores, tended to have larger ribeye area, and had more separable lean tissue, particularly from the chuck, rib, and round than did the nonfed carcasses. These experiments suggest that fed cull beef cows not only accumulate body fat but they replenish or add to other body tissues. These results combined with the grade-yield system further complicate the optimization problem; *ceteris paribus*, increasing the amount of fat decreases yield which results in price discounts, and increasing the amount and quality of muscle tissue increases grade which results in price premiums. Solution requires the precise relationship between skeletal size and composition, weight, grade-yield, and price. This has not been determined fully. In fact, slaughter cow prices are reported only on a grade basis, not a grade-yield basis. Thus, the monthly average prices used in this study average not only over time (days of the month) but also over yield differences within a quality grade class. A solution based on grade averages, however, was thought to be useful regarding the potential gains to producers from grade-price differences as well as indicating the importance of the research question, determining the relationship between weight, grade-yield, and price.

To test the sensitivity of the dynamic programming results to grade-price differences, an alternative method of calculating expected immediate returns for selling and terminal val-

Table 5. Optimal Decisions for Cow Marketing and Expected Present Value of Net Returns from Optimal Policy

Cow Price ($/cwt.)	Month of November, Cow Weight (kg.)					
	350.0	402.5	447.5	500.0	552.5	597.5
	4[a]	4	4	4	3	2
15.00	22.25	24.80	26.71	28.89	29.60	23.56
	5	4	4	4	3	2
17.50	29.65	30.61	31.83	33.99	33.02	24.55
	5	5	5	4	3	2
20.00	36.74	36.84	37.48	39.39	36.29	25.48
	5	5	5	4	3	2
22.50	39.55	40.55	41.34	42.39	37.66	25.89
	5	5	5	5	4	2
25.00	33.75	35.29	36.31	36.63	34.17	21.87
	Month of April, Cow Weight (kg.)					
	350.0	402.5	447.5	500.0	552.5	597.5
	4	4	4	4	3	2
15.00	1.06	1.47	1.72	1.80	1.96	1.12
	5	4	4	4	4	1
17.50	.85	.96	1.07	.98	.89	.00
	5	5	4	4	1	1
20.00	1.34	.72	.50	.17	.00	.00
	5	5	4	5	1	1
22.50	4.85	3.23	1.94	.05	.00	.00
	5	5	5	5	1	1
25.00	8.95	7.14	5.03	2.04	.00	.00

[a] Upper figure is optimal decision; lower figure is expected present value of net returns from an optimal policy.

given an optimal policy, for the stages November and April. The curves on each graph are the boundaries between isodecision spaces, identified by the optimal decision alternative number: 1, sell immediately; 2, feed to maintain cow weight; 3, feed to gain 0.25 kg./day; 4, feed to gain 0.50 kg./day; 5, feed to gain 0.75 kg./day; 6, feed to gain 1.00 kg./day; and 7, feed to gain 1.25 kg./day. Table 5 shows the optimal decision alternative and the expected present value of net returns from an optimal policy for selected states, current price, and weight, for the two stages. Expected present value of net returns is the difference between expected present value of returns from the optimal policy and the return from immediate sale (price times weight). Hence, when the optimal decision is 1, sell immediately, the expected present value of returns from the optimal policy is the current market value and the expected present value of net returns is zero.

Present value of expected net returns from optimal marketing policies varies widely within and between stages. The largest expected net returns, in the range of $20 to $40 more than if cows were sold immediately, result from optimal policies initiated early in the planning period, November and December. As would be expected, the optimal decision or target rate of gain tends to vary inversely with cow weight and directly with current price. At early stages in the planning period, expected net returns increase as cow weight increases through the intermediate weights and then decrease at the heavy weights where holding on maintenance or low rate of gain rations is the optimal decision. At intermediate stages of the planning period, expected net returns from an optimal policy are largest at high current price and low cow weight. For all states, present value of expected net returns from an optimal policy decreases at each succeeding stage to a range of $2 to $15 in March. April is the first month that selling immediately, decision alternative 1, is an optimal decision for any stage in the price range of interest. Through the remaining stages, holding and feeding is optimal only at relatively high current prices, and expected net returns to optimal policies

where $t = 1$ corresponds to November. Parameter estimates were taken as known parameters and the disturbance term u_t was assumed normally distributed with mean zero and variance equal to the square of the standard error of the estimate in the regression model which was 0.928, giving an estimated variance of 0.861. The conditional distribution of P_t, given P_{t-1}, is then normal with mean $\alpha_t + \beta_t P_{t-1}$ and variance 0.861.

A numerical calculation routine for computing the finite state transition probabilities was built into the dynamic programming algorithm because these probabilities were used only once in the algorithm, because the structure in (2) changes by month (stage). This approach is in contrast to the usual procedure of calculating the entire set of transition probabilities separately to be used as input for the dynamic programming algorithm. An important advantage of an integrated program for this type of application is the large saving in computer storage requirements.

There is a problem of truncation in using a discrete valued variable to approximate a continuous variable, such as price in the stochastic dynamic programming model. It is necessary to have upper and lower bounds on price, which requires that the probability of price exceeding the upper boundary must be added to the probability of price falling within the highest price interval; likewise, for very low prices and the lower boundary. This problem was handled by defining extra price states on each end of the interval of primary concern, *viz*, \$15 to \$25. States were defined on the interval \$10 to \$30, providing a \$5 buffer zone on each end of the price interval of primary concern. The \$5 buffer should be adequate in view of the estimated standard deviation of less than \$1.

Terminal Values

The terminal value for any state where cows were held was the value of the cow in that state, which was computed in the same manner as expected immediate returns from selling cows: price times weight. For the state where cows had already been sold the terminal value was zero.

Optimal Marketing Policies

For each state and stage the dynamic programming results show the decision that will maximize expected discounted returns and the value of expected returns from an optimal policy. The return is expected present value of returns from selling a cow less expected costs of feed, labor, and facilities for holding the cow from culling at the beginning of the particular stage until she is sold.

Because of space limitations, the only results presented here are the optimal decisions for two stages, figure 1, and the expected present value of net returns from marketing under an optimal policy for selected states for the two stages, table 5. Figure 1 shows for each state (cow weight and price) in the price range of primary interest, the decision alternative that maximizes expected discounted returns,

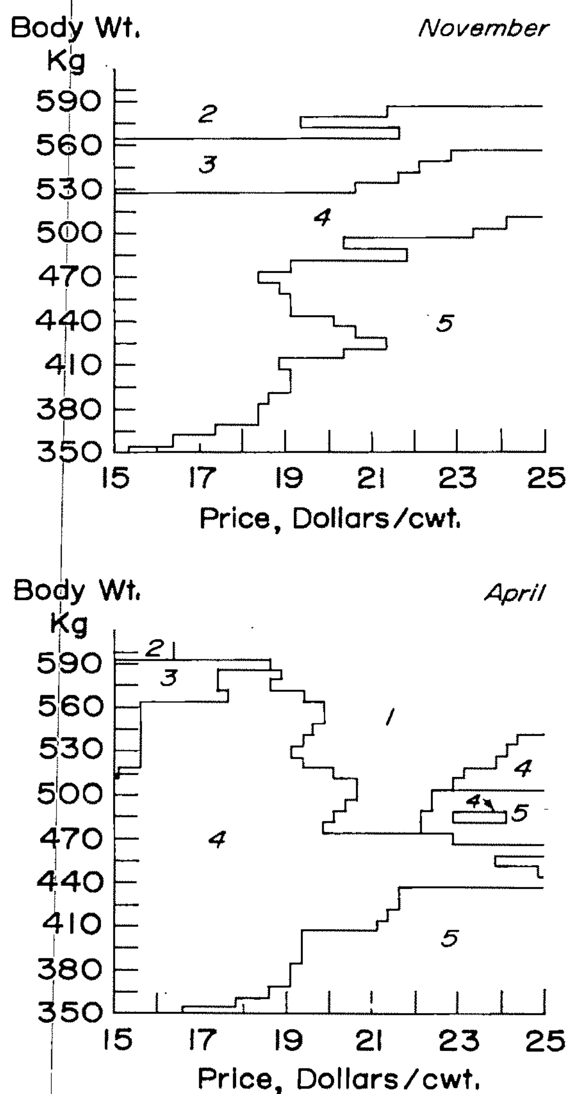

Figure 1. Optimal decisions for cull cow marketing

Table 3. Feedstuffs Considered and Respective Price Per Unit

Feedstuff	Price ($)
Alfalfa hay	
SC-early bloom	40/ton
Brome hay S-C	40/ton
Barley straw	15/ton
Barley grain	5.50/cwt.
Wheat grain, hard red winter	6.00/cwt.
Oats grain	6.00/cwt.
Corn silage	
40% dry matter	14.00/ton
Soybean oil meal 50%	10.25/cwt.
Dicalcium phosphate	14.25/cwt.
Monosodium phosphate	25.00/cwt.
Limestone	1.95/cwt.
Vitamin A supplement	100/cwt.
Dried beet pulp w/molasses	6.50/cwt.
Urea	12.70/cwt.

the high rate of gain rations were composed primarily of the concentrates barley and wheat. The specific blends are fully described in Yager. Daily feed costs are presented in table 4. The anomaly in feed costs at some weight-rate of gain combinations where daily cost was lower for periods of cold than for normal weather results from assumptions on maximum daily intake. During periods of cold, larger daily intake was allowed, which resulted in the substitution of larger quantities of corn silage for concentrates, primarily wheat. The anomaly indicates the interdependence among maintenance requirements, specified rate of gain, daily intake limits, and relative nutrient analysis and prices of feedstuffs considered.

The negative expected immediate return to a decision to hold a cow was then calculated, given a feeding decision, by interpolating over 50-kilogram ranges. The midpoints of the ranges were 350, 400, 450, 500, 550, and 600 kilograms. In those cases where the rate of gain was such that cow weight would change from one 50 kilogram range to another during a month, the different costs per day for the same rate of gain were applied to the appropriate number of days within the month.

Transition Probabilities

The cull beef cow-marketing problem has been formulated as a stochastic decision process, the state of which—at any stage—is controlled by the transition probability density function. Because of the lack of experimental data, weight change was assumed deterministic. Hence, the probability of a given weight is zero or one depending upon the feeding decision made. Only price remains as a stochastic variable in the model.

The price prediction equation for a given month t can be written as

$$(2)\quad P_t = \alpha_t + \beta_t P_{t-1} + u_t, \quad t = 1, 2, \ldots, 12,$$

Table 4. Cost Per Day for Feeding Cull Beef Cows under Various Weather Conditions: Dollars per Day

Decision Alternative k	Rate of Gain (kg./day)	Weather Condition	Cow Weight 350	400	450	500	550	600
		Normal	0.150	0.158	0.173	0.187	0.201	0.214
2	0.00	January	0.168	0.183	0.193	0.207	0.222	0.234
		February	0.152	0.167	0.183	0.196	0.206	0.219
		Normal	0.192	0.207	0.222	0.236	0.250	0.263
3	0.25	January	0.222	0.236	0.244	0.258	0.272	0.285
		February	0.203	0.218	0.233	0.247	0.255	0.268
		Normal	0.264	0.277	0.291	0.315	0.339	0.361
4	0.50	January	0.295	0.308	0.316	0.336	0.360	0.382
		February	0.276	0.290	0.303	0.325	0.338	0.361
		Normal	0.359	0.385	0.409	0.433	0.532	0.627
5	0.75	January	0.391	0.416	0.431	0.454	0.478	0.570
		February	0.369	0.395	0.420	0.443	0.457	0.548
		Normal	0.666	0.779	0.891	0.999	1.113	1.221
6	1.00	January	0.654	0.762	0.824	0.961	1.041	1.148
		February	0.632	0.741	0.852	0.933	1.020	1.127
		Normal	1.300	1.423	1.541	NF[a]	NF	NF
7	1.25	January	1.278	1.401	1.468	1.615	1.729	NF
		February	1.257	1.381	1.499	1.583	NF	NF

[a] NF indicates not feasible.

rate of gain will depend upon cow weight and the ration fed, i.e., level of nutrition provided. From a subset of rations that produce equal rates of gain, a profit-maximizing rancher will choose the least-cost ration. Thus, it is sufficient to specify average rates of gain as decision alternatives if variability of gain is not brought into the analysis. The seven decision alternatives are shown in table 2.

Maintaining, or perhaps increasing, cull cow weight (body condition) on pasture was not considered as an alternative. While it may be that in specific years or at particular times a year pasture, primarily native range in Montana, is a relatively low-cost source of nutrients, daily nutrient intake and performance are even more difficult to predict than is the case with harvested feedstuffs. Decision rules reported later suggest that it would be rare to hold and feed cull cows during the pasture season.

The Discount Factor

The appropriate value for β, the discount factor, represents the opportunity cost of capital, where $\beta = 1/(1 + i)$ and i is the cost of capital. But we also have the multiplicative factor α entering (1) symmetrically with β, where α is the probability that a cow survives one more month. Because of the symmetry, we can simply define a single factor $\delta = \alpha\beta$, which reflects the joint effects of economic discounting and the probability of survival. The results reported here are for $\delta = .9926$ which is equivalent to an annual factor of .9147. For example, an annual discount rate of 6% and survival probability of .97 would correspond to $\delta = .9926$, but many other combinations of discount rates and survival probabilities also would be appropriate for the same factor δ. We note that the economic discount rate should be defined as net of inflation, not the nominal money rate.

Table 2. Decision Alternatives

k	Alternative
1	Sell cows
2	Feed the least-cost ration to maintain cow weight
3	Feed the least-cost ration to produce gain of 0.25 kg./day
4	Feed the least-cost ration to produce gain of 0.50 kg./day
5	Feed the least-cost ration to produce gain of 0.75 kg./day
6	Feed the least-cost ration to produce gain of 1.00 kg./day
7	Feed the least-cost ration to produce gain of 1.25 kg./day

Expected Immediate Returns

At any stage where the decision alternative is to sell a cow, the expected immediate return is the product of the two state variables, price times weight. For any alternative where cows are held and fed, the expected immediate return is negative and equal to feed cost plus a lot charge which assigns a value for facility use and labor allocation. The value for facility use and labor allocation assigned in this study was \$1.50 per cow per month.

Calculation of feed costs, which will vary with cow weight, target rate of gain, and climatic conditions, is a linear programming problem. The objective function to be minimized is a cost equation with price per unit times quantity of each feedstuff constituting the separate terms of the equation. The constraints are nutrient requirements, both maxima and minima, with each term representing the nutrient analysis per unit and quantity of each feedstuff and, of course, nonnegative feedstuff quantities.

Nutritional requirements for many classes of livestock fed for alternative levels of production have been determined and published by the National Research Council. The exception is beef cows fed for changes in body condition—weight gains. Thus, for this study specifying the linear programming constraints necessitated several assumptions, particularly with regard to the energy required to produce various rates of gain on an English breed cow of varying body condition. The assumptions regarding specific daily nutrient requirements, energy requirements for maintenance and for gain, and additional energy required for maintenance during periods of cold (January and February when the mean daily temperature was less than the calculated critical temperature) are fully described in Yager. The feedstuffs considered and respective prices per unit are presented in table 3.

One hundred-eight least-cost rations, one for each of the six cow weights for six rates of gain for three weather conditions, were calculated. The weight maintenance and low rate of gain rations were composed primarily of barley straw. In the intermediate rate of gain rations, straw was replaced by corn silage, while

price elasticities (P-L-H, p. 137) and of income elasticities (Pinstrup-Andersen and Caicedo, p. 407, table 3) in which the respective price and income coefficients for the food commodities are the same or nearly the same (in absolute value). It seems inconceivable for twenty-two food commodities or groups to have the same (absolute) price and income elasticities and is contrary to the empirical evidence available from other studies using time-series data (George and King, Hassan and Johnson 1976, Brandow, Mundlak).

The low (relative to more aggregated commodity groupings) budget proportions of the food commodities (beef was the highest at 10%–12%) used by P-L-H explain how their calculated direct price elasticities could be the same (in absolute values) as the income elasticities. However, if P-L-H's price elasticities based on the Frisch method differ from the true elasticities by amounts similar to the differences in group three of table 1, our suggestion, based on the theoretical and empirical analyses cited earlier, that a higher money flexibility coefficient would be more appropriate would cause P-L-H's Frisch-generated price elasticities to be even further from the true elasticities. This is not inconsistent, however. It only adds to our conviction that the assumption of want independence is not applicable for individual food commodities and that the Frisch method is inappropriate.

P-L-H (p. 136) indicate that data on quantities consumed, prices, and income were collected for two periods in time. An alternative to the Frisch method for estimating price elasticities might be the one used by Hassan and Johnson (1977). Although Hassan and Johnson indicated that their model and method were not elaborate, the estimates of the price elasticities based on cross-section data collected over a one-year period were plausible and consistent with estimates from time-series data.

In conclusion, the authors are to be commended for developing a procedure to examine nutritional impacts of alternative commodity priorities in agricultural research. This, along with their later article (Pinstrup-Andersen and Caicedo), identifies the need to examine the implications of policy recommendations for improving nutritional intake across commodities and across income strata. However, we are disturbed by the seemingly inappropriate application of a technique that was never intended for use in this manner by the original author (Frisch).

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References

Ayanian, Robert. "A Comparison of Barten's Estimated Demand Elasticities with Those Obtained Using Frisch's Method." *Econometrica* 37(1969):79–94.

Barten, Anton P. "Consumer Demand Functions under Conditions of Almost Additive Preferences." *Econometrica* 32(1964):1–38.

———. "Estimating Demand Equations." *Econometrica* 36(1968):213–51.

———. "The Systems of Consumer Demand Functions Approach: A Review." *Econometrica* 45(1977):23–51.

Bieri, Jurg, and Alain de Janvry. *Empirical Analysis of Demand under Consumer Budgeting*. Giannini Foundation Monograph No. 30, University of California, Berkeley, 1972.

Brandow, George E. *Interrelations among Demand for Farm Products and Implications for Control of Market Supply*. Pennsylvania State University Agr. Exp. Sta. Bull. 680, 1961.

Brown, Alan, and Angus Deaton. "Surveys in Applied Economics: Models of Consumer Behavior." *Econ. J.* 82(1972):1145–1236.

Deaton, A. "A Reconsideration of the Empirical Implications of Additive Preferences." *Econ. J.* 84(1974):338–48.

de Janvry, A., J. Bieri, and A. Nuñez. "Estimation of Demand Parameters under Consumer Budgeting: An Application to Argentina." *Amer. J. Agr. Econ.* 54(1972):422–30.

Frisch, Ragnar. "A Complete Scheme for Computing All Direct and Cross-Demand Elasticities in a Model with Many Sectors." *Econometrica* 27(1959):177–96.

George, P. S., and G. A. King. *Consumer Demand for Food Commodities in the United States with Projections for 1980*. Giannini Foundation Monograph No. 26, University of California, Berkeley, 1971.

Green, Richard, Zuhair A. Hassan, and S. R. Johnson. "Alternative Estimates of Static and Dynamic Demand Systems for Canada." *Amer. J. Agr. Econ.* 60(1978):93–107.

Hassan, Zuhair A., and S. R. Johnson. *Consumer Demand for Major Foods in Canada*. Ottawa: Agriculture Canada, Econ. Branch Pub. 76/2, 1976.

———. "Direct Price Elasticity Estimates from Family Budget Data." *Can. J. Agr. Econ.* 25(1977):54–61.

Houthakker, H. S. "Additive Preferences." *Econometrica* 28(1960):244–57.

Lluch, Constantino, Alan A. Powell, and Ross A. Williams. *Patterns in Household Demand and Savings*. London: Oxford University Press, 1977.

Mundlak, Yair. *Long-term Projections of Supply and Demand for Agricultural Products in Israel*. Jerusalem: Falk Project for Economic Research in Israel, Hebrew University, 1964.

O'Riordan, W. K. "The Accuracy of Demand Estimators." *Econ. and Soc. Rev.* 9(1978):125–46.

Pinstrup-Andersen, Per, and Elizabeth Caicedo. "The Potential Impact of Changes in Income Distribution on Food Demand and Human Nutrition." *Amer. J. Agr. Econ.* 60 (1978):402–15.

Pinstrup-Andersen, Per, Norha Ruiz de Londoño, and Edward Hoover. "The Impact of Increasing Food Supply on Human Nutrition: Implications for Commodity Priorities in Agricultural Research and Policy." *Amer. J. Agr. Econ.* 58(1976):131–42.

The Impact of Increasing Food Supply on Human Nutrition: Implications for Commodity Priorities in Agricultural Research and Policy: Reply

Per Pinstrup-Andersen

The author of the comment rightly points out that the validity of the assumption of want independence depends on the level of aggregation of the goods in question and the way in which the aggregation/disaggregation is accomplished. We also agree, as we state in our original article (p. 133), that the assumption of want independence is likely to be violated for some of the commodities included in our analysis. We did not then, nor do we now suggest that the Frisch method be used for estimating price elasticities of demand for individual food commodities, if a better alternative is available. In fact, if the only purpose of the analysis had been to estimate price elasticities of demand, the utility of the exercise would have been questionable. But, as stated on p. 133 of our article, "since the primary purpose of the study was to develop and empirically test a methodology for estimating the nutritional impact of supply expansions, and not to estimate price elasticities per se, it was felt that direct application of the scheme developed by Frisch would provide sufficiently accurate elasticity estimates."

In the particular case, we saw no feasible alternative approach for estimating price elasticities except for a few staple commodities as mentioned below. Thus, the issue at hand was whether the violations of the want independence assumption were sufficiently strong to introduce unacceptable biases in our results. In view of the goal of the analysis, as stated above, the data situation in most developing countries, the urgency of the problem on which the analysis was focused, and the urgency of the related policy decisions, we would settle for directions and orders of magnitudes if great precision could not be obtained. Furthermore, the primary purpose of the analysis was to develop and test an approach and to illustrate its utility for policy making. Providing empirical results for a particular geographical region played a minor role in our objectives, and we stress in the article that the empirical results should be interpreted with caution.

Price elasticities of demand by income group are of paramount importance in studies of the distributional effects of supply shifts among consumers. Income elasticities are obtained with relative ease. Therefore, if budget proportions are known, the income effects of price changes can be estimated. But the substitution effect cannot. Therefore, some recent studies of the market price effects of supply shifts have ignored the substitution effect of price changes. Such an approach is unacceptable in most circumstances, because the income effect of price changes is very sensitive to the budget proportion. The most promising longer-term approach to the estimation of price elasticities of demand for individual food commodities and income strata in developing countries appears to be time-series analyses based on an improved data base. Such data base could be obtained through periodic (repetitive) household surveys. Such data collection is under way in some countries.

In our work, data were available for two time periods. Direct price elasticities of demand were estimated for six staple commodities, simply by comparing prices, quantities consumed, and incomes for the two points in time. The observed change in consumption after adjusting for family size and compositions, was assumed to be due only to price and income changes. Then, the effect of income change was estimated on the basis of income elasticities obtained from cross-sectional data, and the remaining quantity change was assumed to be caused by the observed price change. The six resulting price elasticities were used to obtain six estimates of the money flexibility for each income stratum. As stated on p. 136, these six estimates were not significantly different for any of the income strata. Contrary to the argument made by the author of the comment, the assumption of want independence did not enter into the estimation of these price elasticities.

I am concerned about the use of time-series estimates to judge whether cross-sectional estimates are biased, as done by the author of the comment. There is, I believe, no reason to assume that the former, as a rule, is any closer to the truth than the latter. In a comparative analysis such as the one shown in the comment, this point deserves more than a footnote.

Finally, we acknowledge the error pointed out by the author of the comment with respect to the goal of grouping the commodities. The purpose is, of course, to reduce or eliminate want dependence among groups.

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In our original article we attempted to develop and test a method for estimating nutritional effects of supply shifts and to illustrate the utility of the results for policy making in an area, where additional analytical work is urgently needed. If our analysis has contributed to an expansion of the work by others in that area, including the development of better methods or better data bases for estimating the relevant quantity-price relationships, our efforts were not wasted.

[*Received December 1979.*]

The Demand for Agricultural Research: A Colombian Illustration: Comment

Dana G. Dalrymple

> This is one of those cases where even to argue with a position is to compliment it—one grants it a hypothetical prior existence in order to criticize its "consequences". . . . Gary Wills (p. 125)

In a recent and otherwise fine note, Grant Scobie provides some curious suggestions on the motivation for investment in international agricultural research through the Consultative Group on International Agricultural Research (CGIAR). His comments were not derived from nor proven by his accompanying economic analysis, but rather are conjecture. Even so, they raise important policy issues.

The Scobie Proposals

Basically, Scobie suggests (p. 543) that the motivation for investment in the CGIAR has a domestic "economic rational." While "one should not infer that humanitarian motives are irrelevant," Scobie states that "the returns from that investment come, in part, from cheaper imports, increased export demand, and an enhanced environment for multinational business. . . . The potential benefits" to the donors' consumers "may not be an irrelevant consideration in voting public funds for agricultural research in the tropics." In this way, he notes, the evolving institutional mechanism may be viewed, in part, as serving the same ends as colonial and bilateral precursors "while presumably being more internally palatable."

While it might not seem unreasonable to suggest a combination of economic and humanitarian motives, the critical questions concern the nature and balance of each. With respect to nature, Scobie's proposed internal/domestic economic rational—which I shall refer to as SPIDER—may suggest a mild case of neocolonialism. He is less than precise with respect to balance: both SPIDER and humanitarian motives are posed as "not . . . irrelevant," which gives him a fair amount of room for dodging. Yet the former seems to be emphasized. If so, I would like to suggest the opposite for the 1970s: that humanitarian motives were dominant, while SPIDER was of minor, perhaps negligible, importance. Some less pernicious economic factors may be of increasing importance in the 1980s.

There are, however, methodological problems in resolving these differing perspectives. The subject deals with motivation, and it is difficult to convincingly prove or disprove purity or impurity of motive under the usual rules of evidence.[1] But since Scobie has presented one viewpoint, it may not be inappropriate for me to suggest another and indicate why I hold it. My views are based on an association with the major donor to the CGIAR since 1972—the U.S. Agency for International Development—and participation in CGIAR affairs since 1974. I turn to the past and then to the future.

The Past: The 1970s

The CGIAR was established in 1971 and first provided funding for calendar 1972. As Sir John Crawford, chairman of the Technical Advisory Committee of the CGIAR, put it in 1975 (cited, oddly, by Scobie as support for his rationale):

> The impetus for this action was the desire to encourage more research to assist developing nations increase the quantity and improve the quantity and quality of their agricultural output and thus to raise standards of living. All parties realized that increased agricultural productivity was essential to economic and social development in the great majority of these countries. (p. 281)

As the CGIAR system has evolved, increasing attention has been given to staple food products produced by poor farmers and eaten by poor consumers in the same country.

AID's motivation for support to the CGIAR, insofar as I have witnessed it, has been entirely humanitarian. I have never heard or seen SPIDER used, in whole or part, as a rationale for the pro-

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The views expressed in this note are his own and are not necessarily those of his employers. The author received helpful suggestions from many colleagues—most of whom, he suspects, would rather stay anonymous.

[1] I recall one radio thriller of the 1940s, "The Shadow," which had as its prelude: "Who knows what evil lurks in the hearts of men? The Shadow knows . . . Chortle, chortle, chortle." Perhaps Scobie, even though a New Zealander who may never have heard of the Shadow, has inherited some of his occult powers.

gram. Nor have others in, or formerly in, the agency with whom I have discussed the issue.

But the agency is only part of the story; the source of funding, Congress, must also be considered. It is quite possible that Congress, or some members, may have given more attention to economic factors. But which ones? One which comes to mind has changed over to time. Prior to the late 1960s, agricultural development was not seen as a stimulus to agricultural exports from the United States: in fact, AID was constrained from providing assistance for commodities which were in surplus, such as wheat and rice (National Academy of Sciences). Since that time, it has been recognized gradually that agricultural development in other nations will lead to increased export demand for U.S. agricultural products.[2] This realization may have led to increased congressional support for AID's overall agricultural programs in recent years.

Two other aspects of SPIDER—cheaper imports and "an enhanced environment for multinational business"—played, I suggest, a negligible role. The CGIAR does not support work on the traditional export crops in the developing nations. If some of the basic crops are exported (Scobie notes the case of cassava for animal feed in developed nations), it is a by-product which is heavily influenced by domestic economic conditions and does not necessarily harm the exporting nation or benefit the donor (cassava has a highly inelastic domestic demand; exports from Colombia to the EEC are hardly of benefit to Canada). The effect of CGIAR-sponsored research on multinationals, which base themselves in many countries, is difficult to demonstrate, except as such firms may have been involved in exports of agricultural products and fertilizer from the United States. Whether this process led to significant congressional support for the overall AID agricultural program in the 1970s is most uncertain.

AID, in any case, provides only about 25% of the total CGIAR funding. What can be said of the other twenty-eight donors and 75% of the funding in 1979? Of these, fifteen were other national governments (one of which was a developing nation), four were foundations (counting IDRC of Canada), and nine were international or regional organizations. It is doubtful that the developing nation and the two latter groups—representing, in aggregate, 31% of the funding—had SPIDER as a motive. This leaves the other fourteen developed nations, who contributed 44% of the total funding. I have not seen any evidence to suggest that their motives are other than humanitarian.

The Future: The 1980s

What of the future? I expect to see more of the same motivation: principally humanitarian, with perhaps a growing place for one component of SPIDER—exports to developing nations. In addition, one relatively new factor may emerge.

As agricultural research, along with other factors, stimulates agricultural development, and in turn more general economic development, it may well lead to further imports of agricultural products by developing nations. (These may, however, be different products than those normally consumed and may have a higher price and income elasticity of demand.) The results of this growth process could be beneficial for both exporter and importer. In some cases, the exporter may be another developing nation.

There is another potential benefit which has been hitherto neglected: the potential benefit of the research done in the CGIAR system to the donor. Recently, I have been studying the extent to which the semidwarf wheat and rice varieties developed by CIMMYT and IRRI have been utilized in breeding and production programs in the United States (Dalrymple). There is a definite connection, and it could be expected to grow as the use of semidwarf varieties increases in this country. Obviously, this type of benefit largely will be limited to crops grown in the donor nation, but perhaps some of the research on other crops will have a spillover effect.

A key question is: to what degree concern with benefits dominates the actions of the donor and in turn leads to pressures on the type of research carried out? As long as the returns are a by-product of the systems and do not influence the course of research at the centers, they could be socially useful. If they come at the expense of the welfare of the developing nation, then it is quite a different matter.

Summary

Scobie suggests that both some rather selfish economic motives and perhaps some humanitarian motives may lie behind support for the CGIAR. He appears to rate the former more important than the latter. If this is a correct interpretation, I suggest a different balance. I propose that support through the 1970s was almost wholly based on humanitarian grounds. In the 1980s, however, certain economic motives may begin to play a greater role—but these motives differ and will be of a more benign nature than those suggested by Scobie. Return with us on judgment day in 1990!

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[2] Two of the landmarks in the metamorphosis of the thinking about this issue in the U.S. government were the 1965 bulletin by Mackie and the 1970 speech and subsequent article by West. The matter is further examined in a recent bulletin by Bachman and Paulino.

References

Bachman, Kenneth L., and Leonardo A. Paulino. *Rapid Food Production Growth in Selected Developing*

Countries: A Comparative Analysis of Underlying Trends, 1961–76. Washington, D.C.: International Food Policy Research Institute Res. Rep. No. 11, Oct. 1979.

Crawford, J. G. "Development of the International Agricultural Research System." *Resource Allocation and Productivity in National and International Agricultural Research*, ed. T. M. Arndt, D. G. Dalrymple, and V. W. Ruttan. Minneapolis: University of Minnesota Press, 1977.

Dalrymple, Dana G. *The Development and Spread of Semi-Dwarf Wheat and Rice Varieties in the United States: An International Perspective*. Washington, D.C.: U.S. Department of Agriculture, Agr. Econ. Rep. No. 455, June 1980.

Mackie, Arthur B. *Foreign Economic Growth and Market Potentials for U.S. Agricultural Products*. Washington, D.C.: U.S. Department of Agriculture For. Agr. Econ. Rep. No. 24, Apr. 1965.

National Academy of Sciences. "Global Agricultural Research Organization." *Supporting Papers, World Food and Nutrition Study*, vol. 5, pp. 95–96. Washington, D.C., 1977.

Scobie, Grant M. "The Demand for Agricultural Research: A Colombian Illustration." *Amer. J. Agr. Econ.* 61(1979):540–45.

West, Quentin M. "The Developing Nations and U.S. Agricultural Trade." Talk given at the 1970 National Agricultural Outlook Conference, U.S. Department of Agriculture, Washington, D.C., 16 Feb. 1970; printed under the same title in *Foreign Agriculture*, 6 Apr. 1970, pp. 2–6.

Wills, Garry. *Inventing America: Jefferson's Declaration of Independence*. New York: Vintage Books, 1979.

The Demand for Agricultural Research: A Colombian Illustration: Reply

Grant M. Scobie

> In the United States . . . aid to developing countries has been continuously argued as being in "our country's best interest." (Gunnar Myrdal, Nobel Memorial Lecture, 1975)

My paper made some tentative explorations into the political economy of agricultural research in a developing country. Economists have devoted considerable effort to measuring the impact of technological change stemming from agricultural research. Yet, much less attention has been paid to understanding the forces that bring about public investment in research.

Most of that investment, even in the developing countries, comes from the national fisc. In examining the Colombian case, the major concern of my paper was to offer an explanation for both the level and changing sources of funding for rice research. However, perhaps in the interests of completeness, I included some parallel comments about the motivation for international investments in research. Here, on a relatively minor aspect of the paper, the editors granted me freer rein.

Dalrymple's concern is that I overstepped the bounds of scholarly rigor and offered only some speculation for why we continue to see the industrial nations investing public funds in agricultural research in the less developed countries (LDCs). He states that my comments were not "derived or proven . . . but rather are conjecture." He is correct, of course; and to the extent that conjecture is inadmissable I stand guilty as charged. I must further apologize for the parochial nature of my antipodean origins, alluded to by Dalrymple in his first footnote. My cultural upbringing was certainly not sufficiently rich to capture all the subtleties of his arachnoid analogy!

The central question which Dalrymple raises is whether economic self-interest is a relevant explanatory variable in understanding variations in the level of investment in agricultural research.[1] We both seem to agree that humanitarian motives are important; and despite Dalrymple's defense, the integrity of USAID was not in question. As he goes on to note, it is the source of funding, the Congress, where the interplay of economic and humanitarian interests are focused.

All I claimed was that economic motives may not be irrelevant. Dalrymple strengthens my speculation by citing the explicit congressional constraints placed on AID which, during the 1960s prohibited investment in commodities for which the United States had overproduced. A specific case concerned agricultural research stations in Peru, where no AID funds could be used to support cotton or tobacco research. I am certain that a diligent search of congressional materials would provide ample evidence of such "selfish economic motives."

There is a further test of the hypothesis which awaits only a willing graduate student. Suppose all aid were granted purely on humanitarian grounds. There would be no reason to suppose that the resulting pattern of dispersion of U.S. largesse necessarily would coincide with the self-interest of domestic consumer and producer groups. As a result, a set of potential rents (both positive and negative) would arise. Whenever the decisions of government generate rents (always?), we would expect both potential losers and gainers to expend real resources in endeavoring to modify the decisions—a perfectly rational consequence of a relatively unfettered democratic system.

Such selfish action (called lobbying) will, however, persist only if the expected net returns to the activity are positive. But this can be the case only if the lobbyists are at least partly successful. So that the mere existence of groups presenting evidence before congressional foreign aid hearings would constitute *prima facie* evidence that some economic motives creep in to be mixed with the national humanitarian conscience.[2]

But let me not compound the speculation further. Dalrymple has made an adequate case for the existence of some economic self-interest in the 1960s. Investment during the colonial era in tropical products research (to benefit temperate zone consumers and expatriate plantation owners) provides further historical weight to the argument.

Finally, he concludes that while the 1970s were the golden years of humanitarianism in U.S. foreign

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[1] Dalrymple draws support for his position by arguing the CGIAR has paid increasing attention to research in staple food products. While this may be true in absolute terms, the proportion of the CGIAR budget devoted to basic crop research fell throughout the 1970s as research on livestock production and diseases were funded.

[2] For an example of economic analysis of political (lobbying) markets, see Magee.

aid policy, some grubby bits of self-interest may be creeping into the 1980s. So two of the three decades he chose to present support the simple point: economic motives may not be irrelevant (with the possible exception of the 1970s).

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Reference

Magee, S. P. "Three Simple Tests of the Stolper-Samuelson Theorem." *Current Issues in World Trade and Payments*, ed. P. Oppenheimer. London: Routledge and Kegan Paul, 1979.

Financial Impacts of Government Support Price Programs: Comment

Peter J. Barry

Michael Boehlje and Steven Griffin (BG) provide a timely, relevant analysis of the financial impacts of U.S. government price programs that is rigorous in its use of valuation concepts under risk, practical in its simulation approach, and clearly in the spirit of responding to needs for policy-related research. Their major objective is to evaluate how price support programs influence investment and financing behavior of agricultural producers with different financial characteristics and sizes of operation. They reason that indexed support prices will provide greater certainty in farmers' cash flows and thereby reduce financial risks, with more rapid farm growth resulting from increased bid prices for durable assets, especially land, increased debt capacity, and higher financial leverage.

Their simulation analyses for farms differing in size, capital structure, and farmer characteristics under selected parameter values indicate that smaller, more highly leveraged operations generally will receive fewer benefits from a cost-of-production-indexed price support program than will larger operations with lower financial leverage. As a result larger, higher-equity operations can bid higher prices for land and should show more rapid growth in net worth, land ownership, and standard of living. The authors conclude with a plea that future analyses more fully account for policy impacts on farms with different financial, economic, and producer characteristics.

My response to this kind of analyses is quite positive and I fully support BG's efforts. My comments here consist of two sets of concerns whose resolution should further clarify their analytical approach, strengthen the generality of their results, and perhaps provide for extended analysis. One set of concerns addresses the need for more information to understand fully the specifications and assumptions embodied in their simulation model. The second set, which is closely related to the first, considers how the initial estimates of bid prices for land might respond to changes in some of these model specifications and assumptions. While Boehlje and Griffin attribute much of their results to differences in farms' financial characteristics and debt-servicing capacity, I suspect that the interrelationships of those financial characteristics with the influences of several other factors are more important than their article implies. My approach is to identify these other factors, briefly discuss their implications, and then use an alternative valuation model to show some of their effects on initial bid prices for land.

The model assumptions, specifications, and other factors needing clarification and explanation are (*a*) the farmers' planning horizon, (*b*) the farmers' risk properties, (*c*) the derivation of capitalization rates, (*d*) income tax specifications, (*e*) financial constraints, (*f*) economies of size, (*g*) land indivisibility, and (*h*) leasing.

The valuation model specified by BG in equation (1) (p. 286) shows a perpetual income stream $E(R_t)$ which, in turn, implies an infinitely long valuation horizon. However, the characteristics ascribed by BG to their three farm situations, upon which numerical analysis is based, imply important differences in planning horizons. Surely the youthful operator of Farm A has a longer horizon than the "more typical" operator of Farm B, who in turn has a longer horizon than the "well-established" operator of Farm C. If so, then these differences may influence the structure of the valuation model as well as resulting bid prices and growth potential.

Information on risk properties that characterize the operators of the three farms also is difficult to identify. BG indicate that the "potential land purchasers are risk-averse." They include an undefined δ term as a determinant of cost of capital in equation (10) (p. 287) which presumably reflects the degree of risk aversion. However, no information is given about the level of risk aversion, how it differs among the three farmers, how it responds to changes in wealth during the simulation period, and how changes in these specifications might influence the results. Similarly, expectations held by the three farmers are assumed the same.

Additional information on these risk properties appears essential. As it stands now, one is led to conclude that there should be important differences in risk aversion, expectations, or both, among the three farmer types. Suppose, for example, that the beginning portfolio compositions of Farmers A, B, and C are optimal with respect to a decision criterion like expected utility maximization. Furthermore, the asset mixes and expectations of the three farms essentially are identical. They differ primarily in financial structure and in farm size. Then, the differences in financial structure largely should be attributed to differences in risk aversion. Spe-

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cifically, the lower leverage and therefore lower financial risk for Farmer C implies that he has higher risk aversion than Farmer B, who in turn has higher risk aversion than Farmer A. If risk aversion indeed does differ among the three farm situations, then the model should show this through differences in capitalization rates which may strongly influence resulting bid prices.

Procedures used to derive numerical estimates of the capitalization rate in equation (9) (p. 287) are not clear. BG indicate that their capitalization rate is related functionally to the values of several variables according to a specific form used by Lee and Rask. However, Lee and Rask assumed a specific capitalization rate based on opportunity costs of capital and used this rate together with cash flows determined by several other variables to estimate bid prices for land. Hence, the linkage between the Lee and Rask approach and BG's procedure is obscure.

Furthermore, it is not clear how BG derived the specific numerical values for their capitalization rates. First, the capitalization rate used for Farm C is higher than for Farm B which is higher than for Farm A. This pattern is consistent with differences in risk properties identified above, although the lack of any discussion of risk properties makes this explanation doubtful. Instead, the differences in capitalization rates may be due to differing income tax rates for the three farm situations.

A second concern is BG's specification that the capitalization rate is reduced by the expected rate of growth in land values. As shown in finance literature (e.g., Van Horne, p. 22), it is appropriate to value a perpetual income stream that is expected to grow at a constant rate (g) by capitalizing the first period's nominal income value at a rate that is reduced by the expected growth rate. However, there is no single growth rate in BG's analysis. In fact, five inflation rates apparently are used. Production costs inflate at a 6% annual rate, prices received at a 2% rate, net income per acre at a 3% rate, land prices at a 5% rate, and general prices at a 6% rate. In addition, crop yields increase at a 1% annual rate. Given this complex of rates, what basis is there for reducing the capitalization rate by the expected rate of growth in land value, especially since this growth rate only indirectly affects growth in annual income through the indexed price support mechanism?

Procedures used to account for the effects of income tax obligations in the valuation model also are obscure and ambiguous. It is difficult to tell whether the analysis occurs on a before-tax or after-tax basis. The authors indicate that the capitalization rate [equation (9), p. 287] is functionallly related to the marginal tax rate, although it is not clear how tax obligations are expressed in its calculations. The text (p. 289) also indicates that expected annual income is measured on an after-tax basis; however, calculation procedures illustrated in table 2 (p. 291) do not show the deduction of income taxes from annual income, only the deduction of land taxes. Perhaps this specification of the valuation model means that accounting for income taxes in the income flow and in the capitalization rate have offsetting effects, leaving bid prices the same on a before-tax or after-tax basis.

The authors' specifications of financial constraints in equations (12) and (13) (p. 287) for the three farms appear consistent with those used in rural financial markets by commercial banks, production credit associations, and federal land banks. However, these specifications allow potential levels of debt use that are inconsistent with each farm's initial financial structure and implied risk properties. Farmer C, for example, has a financial structure with much less leverage and financial risk than Farmer A. Now, however, C is allowed to outbid A for land primarily on the basis of his operation's greater debt capacity. But, will he indeed do so if his aversion to risk and preference for liquidity exceed those of A?

Economies of size and the forty-acre indivisibility assumption are model specifications that significantly affect numerical results. However, they are treated quite lightly in the analysis. For size economies, is it reasonable to assume that the differences in economies continue to hold as the three farm types grow over time? Or, does narrowing of differences enhance the bidding potential of small operations for land as growth occurs?

The forty-acre lower bound on incremental land acquisition most heavily affects smaller operations like Farm A. Forty acres may be a realistic lower bound, although greater flexibility in sizing of land tracts appears to be occurring in order to make land acquisition more feasible for more purchasers. Varying the indivisibility specification might be useful in further analysis.

Finally, the analysis could be extended to account for the effects of price support programs on leasing assets. Leasing is an especially important resource control method for farm land due to high land values and farmers' limited financing capacity. Analogous to the author's present approach, one could estimate maximum rents that could be bid for land under various assumptions on farm size, capital structure, behavioral and other operator characteristics, and price support provisions.

BG's results can not be reproduced exactly here due to the complexity of the simulation model and its lack of availability. Hence the following analysis formulates an alternative valuation model in order to illustrate the effects of variations in several model specifications and parameter values on the initial bid price for the three farm types.

The model is formulated as

$$NPV = -INV_{dp} + \sum_{n=1}^{N} \frac{P_1 (1+g)^n (1-t)}{(1+i)^n} - \sum_{n=1}^{N} \frac{F_{nt}}{(1+i)^n} + \frac{V_N - T_N - D_N}{(1+i)^n},$$

Table 1. Parameter Values

	Farm A	Farm B	Farm C
Planning horizon (n)	30 years	20 years	10 years
Initial annual income (P_1)	\$56.68	\$66.18	\$100.75
Growth in annual income (g)	3%	3%	3%
Initial land value (INV)	\$1,770	\$1,770	\$1,770
Growth in land value (a)	5%	5%	5%
Marginal tax rate (t)	22%	32%	50%
Discount rate ($i = .0544 + \delta\ \sigma^2$)	10%	12%	14%
Discount rate after taxes	7.80%	8.16%	7.00%
Risk aversion (δ)	1.0741	1.5905	2.1069
Down payment ($INV.20$)	\$354	\$354	\$354
Mortgage interest rate	9%	9%	9%
Loan length	30 years	30 years	30 years

where NPV is net present value, INV_{dp} is the down payment requirement for land price INV, g is the annual growth rate of net income, t is the marginal tax rate, and F_{nt} is the annual debt amortization commitment adjusted for any tax savings associated with the interest portion. Variable V_N is the land's value at the end of the planning horizon. It is defined as $V_N = INV(1 + a)^N$ where a is the annual rate of increase in land value. Variable T_N is any tax obligation on capital gains and D is debt outstanding at the end of year N. Variable i is the discount rate defined as $i = (i_f + \delta\sigma^2)\ (1-t)$, where i_f is a risk-free rate, σ^2 is the variance of income, and δ is a risk coefficient.

Initial parameter values are shown in table 1. Marginal tax rates, levels and growth rates of annual income, and land appreciation are the same as in BG. Different lengths of planning horizon reflect the farm characteristics discussed earlier. Financing terms for land include a 20% down payment with the balance repaid in equally amortized annual payments over thirty years at 9% interest. Levels of risk aversion are selected arbitrarily to yield before-tax discount rates of 10% for Farm A, 12% for Farm B, and 14% for Farm C. On an after-tax basis, these rates are 7.80%, 8.16%, and 7.00% respectively.

Initial bid prices shown in table 2 are calculated as the land's asking price (\$1,770) plus or minus the $NPVs$ derived with the valuation model. Results are shown first for equal planning horizons and then for different horizons. In each case, $NPVs$ are derived without either debt financing or income taxes, and then with these specifications included. The top row of table 2 indicates bid prices without either debt financing or income taxes, and with a ten-year horizon for each farm. Farm A exhibits the highest bid price, followed by C, and then B. Moving down the table shows the important effects which taxes, financing, planning horizon, risk premiums, and their interrelationships have on ranking and level of investment profitability. Substitution of lower cost debt for higher cost equity increases the profitability of the land investment for each farm, although favoring the larger operations whose size economies provide for larger annual incomes. Moreover, on an after-tax-basis debt financing favors farms (e.g., Farm C) with higher tax rates due to higher tax savings arising from payments of tax-deductible interest.

Lengthening the planning horizon to thirty years for Farm A and twenty years for Farm B increases the present values of the annual income flow due to the added years of discounted income. However, longer horizons also reduce the present value of the land's terminal market value because the discount rate exceeds the annual rate of increase in land value. The net effect here is that the reduction in

Table 2. Initial Bid Prices for Land

	Farm A	Farm B	Farm C
10-year horizon			
No debt or taxes	\$1,499.11[a]	\$1,345.44	\$1,361.59
No taxes	1,583.53	1,577.59	1,719.27
No debt	1,899.77	1,588.02	1,751.47
Taxes and debt included	1,712.08	1,773.87	1,991.06
Different planning horizons	30 years	20 years	10 years
No debt or taxes	1,132.29	1,083.91	1,361.59
No taxes	1,248.98	1,378.72	1,719.27
No debt	1,407.49	1,444.23	1,751.51
Taxes and debt included	1,523.50	1,700.97	1,991.06

[a] Initial bid prices are calculated as the land's asking price INV = \$1,770, plus or minus the net present values derived with the valuation model.

present values of terminal market value outweighs the increases in present value from annual net income, thereby reducing the bid prices for land as the planning horizon lengthens.

The resulting order and magnitude of bid prices in the bottom row are about the same as the initial bid prices found by BG (table 2, p. 291). Moreover, the higher risk premiums for Farms B and C do not change the ordering of bid prices, although they do reduce the differences in bid prices that would occur if each farm had the same level of risk aversion. Further calculations show that the before-tax discount rates for Farms B and C would have to be about 15.2% and 44.5%, respectively, in order to yield the same bid prices as Farm A ($1,523.50) in the bottom row of table 2.

In concluding, my major points are that further explanation on model specifications and assumptions should clarify BG's analytical approach, and that the causal factors explaining why larger, higher equity operations tend to be favored by indexed price support programs may be broader than their analysis indicates. The alternative valuation model used here is much less detailed than BG's, and still fails to consider factors such as indivisibility, renting, and changes in size economies; however, it yields results that appear substantive enough to warrant further analysis with their model. Planning horizons, tax obligations, debt financing, size economies, and risk-liquidity properties all play important, interrelated roles. And, hard as they are to measure, we still do not know enough about farmer's risk and liquidity preferences, and how they respond to changes in business and personal characteristics. Nonetheless, they too need consideration in policy analyses like this one.

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References

Boehlje, M. D., and Steven Griffin. "Financial Impacts of Government Support Price Programs." *Amer. J. Agr. Econ.* 61(1979):285–96.

Lee, W. F., and N. Rask. "Inflation and Crop Profitability: How Much Can Farmers Pay for Land." *Amer. J. Agr. Econ.* 58(1976):984–89.

Van Horne, J. C. *Financial Management and Policy*, 4th ed. Englewood Cliffs, N.J.: Prentice-Hall, 1977.

Financial Impacts of Government Support Price Programs: Reply

Steven Griffin and Michael Boehlje

Peter Barry has provided an insightful and constructive comment on our evaluation of the financial impacts of government price support programs. He raises several issues which require further clarification and explanation.

Planning Horizon

Our assumptions concerning the planning horizons of the representative farms were not made clear in the original article. Barry, however, did surmise correctly that the three farm situations imply important differences in planning horizons. The "youthful" operator of Farm A was assumed to have a longer planning horizon (thirty years) than the "more typical" operator of Farm B (twenty-five years), who in turn was assumed to have a longer horizon than the "well-established" operator of Farm C (twenty years). These parameters were inadvertently left out of table 1 (Boehlje and Griffin, p. 290).

As Barry states, "longer horizons increase the present values of the annual flow of net income from the land due to the additional years of income to be discounted." However, longer horizons reduce the present value of the land's terminal market value if the discount rate exceeds the assumed rate of increase in land value. Additional analyses with the simulation model indicate that if Farms B and C were assumed to have the same planning horizon as Farm A (thirty years) and other parameter settings remain unchanged, the maximum bid prices for land are slightly smaller than the original estimates. In year 1, for example, Farm B's maximum bid price with a thirty-year planning horizon is \$1,593 compared to \$1,638 with a twenty-five-year horizon; Farm C's maximum bid with a thirty-year horizon is \$1,938 compared to \$1,955 with a twenty-year horizon. Because the small farm's maximum bid price is now closer to that of the larger operator, its growth potential would be expected to be enhanced. However, simulation results indicate the converse is true. With longer planning horizons, and lower bid prices for land, the larger and/or high equity farms acquire acres even faster while the smaller, low equity farm still does not have sufficient cash flow to implement a purchase.

Related to the planning horizon is the amortization period of the loan. The Lee and Rask formulation of the capitalization model used in our study constrains the amortization period of the loan to less than or equal to the planning horizon (Lee and Rask, p. 986). Consequently, we did not analyze situations, such as Barry presents (in his table 1), where the planning horizon is significantly shorter than the loan length.

Risk Properties

The risk parameter (δ) is calibrated by the following equation

$$(1) \qquad \delta = (W_2 - CC_o)\ \sigma_{p_o}{}^2,$$

where W_2 is the maximum allowable opportunity cost of capital (after taxes), CC_o is the after-tax opportunity cost of capital in the base period, and $\sigma_{p_o}{}^2$ is the price variance in the base period. CC_o was assumed to be 8%, W_2 was set at 10% (table 1), $\sigma_{p_o}{}^2$ was calculated at $(.1968)^2$ (see figure 2, panel 3 of the original article), and therefore δ was equal to .000746 for all farm situations. Note that relative risk aversion does not respond to increases in wealth and that price risk (on a per acre basis) is the only source of risk (i.e., there is no production risk or price risk on inputs).

We also would note that differences in financial structure between farms may not necessarily represent relative aversion to risk. The financial structure of a firm at any point in time may be as much (or more) a function of the initial endowment or the number of years the firm has been in existence as risk aversion. Also there are a number of ways to handle risk, such as diversification and use of various marketing strategies in addition to leverage and portfolio adjustments; so differences in financial structure need not imply differences in risk aversion.

The Capitalization Rate

We assumed the value of an asset, V_t, is equal to the expected income stream $[E(R_t)]$ capitalized by the appropriate rate (k_t) (Boehlje and Griffin, p. 286).

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Thus, the implicit capitalization rate can be determined as

$$K_t = \frac{E(R_t)}{V_t}. \tag{2}$$

By means of the capitalization formula suggested by Lee and Rask (p. 986), the V_t of equation (2) above can be calculated. Eleven variables or parameters are required to solve the Lee-Rask model for the maximum bid price, V_t (P^* in Lee-Rask notation). These include $\bar{P}$, the average price per acre from recent sales of comparable parcels; CC, the buyer's opportunity cost of capital after taxes [Boehlje and Griffin, equation (10), p. 287]; m, the buyer's planning horizon in years; ANI, the expected annual net return per acre before taxes; GNI, the expected annual rate of growth in annual net returns per acre; MTR, the buyer's marginal income tax rate; DP, the proportion of the purchase price paid down; n, the nominal rate of interest charged on the mortgage loan; t, the amortization period on the loan; GLV, the expected annual rate of inflation in land values; and finally, T^*, the tax rate that will apply to the capital gains income realized at the end of the planning horizon. For simulation purposes, $\bar{P}$ was assumed to be the previous year's "market" price for land, n was equal to t, and T^* was equal to one-half the marginal tax rate.

Therefore, we can determine the implicit capitalization rate, k_t by equation (2) above since $E(R_t)$ is the variable ANI just defined. Differences in capitalization rates between the farm situations simulated result primarily from differing marginal tax rates, amortization periods, and planning horizons.

The Lee-Rask formula treats capital gains in farm land values in the conventional manner (i.e., computing the present value of the capital gains after taxes when the property is sold or at the end of the planning horizon). Therefore the capitalization rate does not reflect any value of unrealized capital gains (Plaxico and Kletke). Unrealized capital gains do however facilitate the implementation of a purchase since such land value increases add to the wealth (equity) of the owner and reduce the degree to which equity is leveraged.

Barry also questions the basis for "reducing the capitalization rate by the expected growth rate in the value of land." The adjustment for the "expected annual rate of inflation in land values" is included explicitly in the Lee-Rask formulation of the capitalization model (Lee and Rask, p. 986). This parameter was defined as GLV in our analysis and specified at 5%. Our description of this adjustment may have been confusing. In footnote 6, we were merely reminding the reader how a capitalization rate can be less than the lowest possible (risk-free) discount rate of the buyer. We did not intend to imply that the capitalization rate derived from the Lee-Rask model was (once again) reduced by the expected growth in the value of land.

A further issue is whether or not one should allow the farm operators to adjust their expectations (especially with regard to land price inflation) to the growth rates experienced during the simulation. We did not include such adjustments. If farmers are assumed to "learn the game," especially the manner in which the support program validates any land price increases, the time path of land values is particularly explosive (Harris). It would be unreasonable to expect that farm policy makers would allow such an explosive mechanism to track very far into the future.

Income Tax

As suggested by the Lee-Rask formulation of the capitalization model, all calculations are on an after-tax basis. In table 2 of the original article, these adjustments already have been accounted for in determining the implicit capitalization rate. Contrary to Barry's comment, Lee and Rask found the maximum bid price for land to be "relatively insensitive to changes in the marginal tax rate" (Lee and Rask, p. 987).

Income tax rates also have an effect on the optimum amount of leverage which should be employed. If the opportunity cost of capital is less than the after-tax rate of interest, the highest maximum bid price would occur with a 100% downpayment. In our simulation analysis with the base opportunity cost of capital assumed to be at 8% and mortgage money available at 8.75%, the marginal tax rate would have to be less than 9.14% before high down payment financing would yield higher maximum bid prices.

Financial Constraints

Our analyses assumed that farmers are constrained financially by their lenders (i.e., no internal capital rationing is assumed). As Barry agrees, the constraints incorporated in the model are consistent with those used by lenders in rural financial markets.

We would caution that determination of an asset's "worth" is not synonymous with the feasibility of its purchase; consequently, our analyses separated the determination of the bid price from the process of implementing and financing a purchase. The point to be emphasized (which is not part of Barry's model or analysis) is that the financial feasibility (i.e., the ability to obtain the downpayment and service the annual debt obligations) of a purchase must be evaluated separately from the determination of an asset's value.

Economies of Size

In our analyses, the smaller farms are assumed to move down the long-run average cost curve as they

grow larger. Therefore, the smaller farm which grows over time to 640 acres reaps the economies of size which benefited the 640-acre larger farm initially. Inflation over time does shift the long-run average cost curve vertically.

The Minimum Incremental Land Purchase

In the original analysis, purchases of land could be made at the "national average" price if the farm could meet the down payment, cash flow, and financial ratio requirements for a minimum size parcel of 40 acres. While we agree with Barry that a minimum size of 40 acres has a more serious impact on small or low-resource farms, a similar plight affects them in reality. Subsequent analyses assuming a minimum tract size of 20 acres did enable the smaller, low equity farm (Farm A) to expand from 160 to 253 acres compared to no expansion in the original analysis, but this expansion occurred primarily during the last five years of the planning horizon. Furthermore the 20-acre minimum enhanced the growth rate in acreage and net worth of the two larger farms as well, although the change was not as large percentage-wise as with the smaller farm.

Leasing

Extending our analysis to include leasing as an alternative method of resource control would indeed be interesting. Leasing does provide the small landowner-operator the means to gain economies of size without the outlays and financial requirements of outright land purchase. However, one would expect that financial differences (leverage, taxes, etc.) among farms would be reflected in their maximum bid prices for annual leases in a similar fashion as occurs in the maximum bid price for land purchases. Competition among farmers for leased land could be expected to drive rental rates up to the point where zero net returns to leasing occur for the most efficient leasee. Thus, the primary economic benefit of leasing for the small landowner would be the extra residual income from his owned land due to his lower average cost of production with the larger total acreage.

In summary, we appreciate Barry's review and constructive comments. His questions have enabled us to clarify our analysis procedures, and he has encouraged us to examine in more detail the causal forces underlying our empirical results and conclusions. This reexamination based on additional numerical analyses corroborates our original results and lends further strength to our conclusions.

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References

Boehlje, Michael, and Steven Griffin. "Financial Impacts of Government Support Price Programs." *Amer. J. Agr. Econ.* 61(1979):285–96.

Harris, Duane G. "Inflation-Indexed Price Supports and Land Values." *Amer. J. Agr. Econ.* 59(1977):489–95.

Lee, Warren F., and Norman Rask. "Inflation and Crop Profitability: How Much Can Farmers Pay for Land?" *Amer. J. Agr. Econ.* 58(1976):984–90.

Lee, Warren F. "A Capital Budgeting Decision Model for Evaluating Farm Real Estate Purchases." *Can. Farm Econ.* 11(1976):1–10.

Plaxico, James S., and Darrel D. Kletke. "The Value of Unrealized Farm Land Capital Gains." *Amer. J. Agr. Econ.* 61(1979):327–30.

Cattle As a Store of Wealth in Swaziland: Comment

Lovell S. Jarvis

In a recent article in the *Journal*, Doran, Low, and Kemp (DLK) argue that Swazi herders hold cattle as a store of wealth apart from their productive value. In Swaziland, "insofar as cattle are regarded as an end in themselves, they cannot be likened to conventional disposable productive assets which are held as long as their capital value in production exceeds their current market value" (DLK, p. 42). DLK believe that the store-of-wealth motive induces herders to maintain individual animals beyond the age of optimum slaughter (for beef purposes) and to increase the herd beyond the size which would maximize beef production. In support of this hypothesis, DLK draw on a variety of beef industry statistics.

DLK then argue that a failure to consider the store-of-wealth motive has led to the implementation of counterproductive livestock development programs in Swaziland in recent years. They believe these programs have exacerbated, rather than alleviated, the overgrazing problem, inducing an increase in the national herd greater than the increase in forage. They propose that measures be implemented to induce stockholders to sell more cattle or, if necessary, to enforce control of cattle numbers below the current level.

I believe DLK misunderstand the link between beef production and the use of cattle as a store of wealth and exaggerate the depressing effect of the latter on the former. The principal production problem in Swaziland, overwhelmingly so, would seem to be the communal grazing system used by Swazi herders. This factor by itself is capable of explaining the overgrazing, advanced age of slaughter, and the other herd characteristics cited in their article as being evidence of the store-of-wealth motive. If a choice has to be made as to which of the two factors is the most damaging to beef production, the theoretical and the empirical evidence appear strongly in favor of communal grazing.

Accordingly, I feel DLK have not presented convincing evidence that the livestock development programs enacted in Swaziland have been counterproductive. They will not solve the communal range problem, which requires decisions currently politically unpalatable, but the development programs being implemented appear to be attractive second-best alternatives. Beef production has grown rapidly in recent years in spite of the communal range problem, probably because of these development programs, and the latter may gradually help induce Swazi herders to convert public ranges to a system of private control.

The Store of Wealth

DLK provide no precise theoretical definition of the term store of wealth, nor a framework within which its impact on resource allocation can be rigorously analyzed. Their concept of the store-of-wealth function is broad, however, apparently including both the benefits received from cattle used as a money substitute (whether in trade or for asset accumulation), and also those received directly from ownership, such as security and prestige. DLK believe that Swazi herders maintain animals largely for these benefits and hold that Swazi herders are little motivated by market incentives.

Nonetheless, considerable evidence is given in DLK's article that Swazi producers are commercially oriented. I will comment later on this evidence. I believe that cattle serve as a store of wealth in Swaziland precisely because they are widely perceived to be productive assets. Their exchange value, determined chiefly by their use as a source of milk, beef, and hides, and as draft animals, is established in orderly markets. Cattle have value because of their ability to convert forage into useful products, and wealth can be invested in cattle with the likelihood of increase, not just preservation. The wide appreciation of their value, and their relative ease of transport (on foot), means that cattle can be liquidated easily. Owners of cattle derive security from the exchange value of their animals, and may obtain status and prestige among other persons because of this economic wealth. However, owners will find it profitable to prolong the life of an individual animal only so long as its daily production (including future beef) exceeds its current value as beef and hide. Individual animals cannot be kept beyond some specific age except at an economic loss.

While cattle can produce store-of-wealth benefits of the type suggested by DLK, these benefits will be joint products with beef.[1] The production of both

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[1] While Swazi herders also maintain cattle for their milk and for draft purposes, I will refer exclusively to beef as the commercial product sought in the rest of this paper. Inclusion of the other products complicates the model without changing any important results in the current context. These other products should be remembered when designing agricultural policy, nonetheless.

store-of-wealth benefits, and also beef, will induce producers to accept a rate of return on the capital invested in cattle lower than it would be if beef were the only product. The allocational impact of the store-of-wealth function is then comparable to a reduction in the interest rate. As is shown later, the magnitude of this impact in Swaziland is surely small.

Evidence on the Beef Production Motive in Swaziland

What evidence contained in the article by DLK supports the hypothesis that Swazi herders produce animals for commercial ends?

First, DLK indicate that cattle prices in Swaziland are determined by those in South Africa, which is the major export market for Swazi cattle. DLK actually use South African prices as a proxy for Swaziland prices in their empirical work. Swazi herders have access to a viable commercial beef market whose magnitude, in both physical and value terms, has grown significantly during the last two decades. The prices quoted by DLK indicate that cattle have substantial value when slaughtered. It is a simple, but strong, argument that producers in this situation will be aware that wealth can be optimally accumulated by selling older animals when they have reached the economically defined age of slaughter, reinvesting in younger animals.

Second, individual Swazi citizens are said to have the opportunity to earn cash, including South African Rands, through various means—cattle, cotton, and tobacco production and wage employment in South African mines. Their pursuit of these activities indicates an interest in obtaining cash which, as a monetary asset, seems widely demanded and accepted. Cattle are another asset which may satisfy exchange and accumulation needs, but would have significant disadvantages vis-à-vis cash, save that they increase in value as they grow.

Third, the offtake rate from the cattle herd is estimated to average about 9%, but DLK mention additional growth in the herd of about 3% per year over the period studied. These data suggest an extraction rate of about 12% per year. This may be compared with the extraction rates in Uruguay and in Brazil, two other countries in which commercial cattle ranching with land-extensive technology is important, and with that on European-owned ranches in Swaziland. In the period 1950–60, previous to the introduction of improved pastures, the extraction rate in Uruguay averaged about 16% (Perez and Secco). In Brazil in 1970, the extraction rate was 15% (Lattimore and Schuh). Within Swaziland itself the extraction rate from European-owned herds, said to be efficiently operated on freehold land, is estimated at 14% (IBRD). The extraction rate from the Swazi herd is lower, as one would expect given the sector's lower development and its communal ranges, but it is still significant. Swazi producers appear concerned with the sales aspect of their cattle enterprise.

Fourth, DLK indicate that government-owned and managed ranches have been established in recent years to fatten Swazi cattle prior to slaughter. The average slaughter value of animals finished on these ranches, when compared with that of animals finished on a Swazi grazing area, is US $50 higher. An increasing number of Swazi cattle have been directed to these ranches since their establishment, indicating a desire by individual herders to obtain greater output and income.

Fifth, DLK empirically confirm a negative short-run price response of cattle slaughter in Swaziland. Jarvis (1974) has shown that this is the expected result where cattle producers are attempting to increase beef output in response to a beef price increase, i.e., where cattle production is essentially commercial. DLK instead argue that this result occurs because producers are not interested primarily in the beef production potential of cattle. They state that producers sell animals only "to meet specific cash needs (so that) the minimum number will be sold. Factors that increase the market value of cattle will enable the owner to meet his cash needs by selling fewer animals" (DLK, p. 42). I will show later that the empirical evidence contained in DLK does not support their hypothesis, while it does support that of Jarvis. Accordingly, I feel the negative price response is additional evidence of commercial interest on the part of Swazi herders.

The Relative Impact of the Store of Wealth and of Communal Ranges on Production of Efficiency

Assuming that cattle are held principally for income production, but also may provide benefits as a store of wealth, I now examine the impact of the latter factor on beef production. Simultaneously, I can analyze the allocational problems associated with the use of communal (as opposed to private) range lands in Swaziland. I then compare the two effects.

The discussion which follows is based on the argument presented in Jarvis (1974). Under conditions of private range ownership, perfect competition in product and factor markets, and producer efforts to maximize income, the unit price of beef, P; the cost of inputs required by the animal, including feed, C; and the interest rate, r, will be determined endogenously to the livestock sector (or the economy as a whole). However, individual producers must take these values as given, from which they determine the optimum stream of inputs, $\hat{I}$, to be provided to animals, and the optimum age of slaughter, $\hat{\theta}$. Given the resources available, including land, individual efforts will optimize the value of sectoral output.

Change in the parameters P, C, and r, brought about by exogenous events, will affect producers' decisions regarding $\hat{I}$ and $\hat{\theta}$ in a predictable fashion. In particular, an increase in beef price, or a de-

crease in feed cost or in the rate of interest, will cause a short-run reduction in slaughter. Heuristically, the negative short-run price response is explained as follows. A price increase leads producers to expand production. Production is composed of both slaughter and the change in herd size. To increase future slaughter, current slaughter is reduced; steers will be fattened to heavier weights and additional females will be retained for the breeding herd. In the longer run, slaughter will increase.

Given this framework, the impact of the demand for animals as a store of wealth on beef production can be shown to be small. If individuals are willing to receive part of their return from investments in livestock in the form of services, the average return to cattle investments, as measured by their slaughter receipts, will be forced lower in a competitive market. The impact is similar to that caused by a reduction in the interest rate, r, which will extend the optimum age of slaughter and reduce the optimum feed input. However, the store-of-wealth effect does not introduce a market distortion. To the extent that it exists, producers choose to substitute one benefit for another and no welfare loss is implied. Further, the store-of-wealth effect will have no severe impact on beef production because it affects the feed-beef conversion process only at the margin. Only a small proportion of the herd is affected directly. As the total forage available is not affected by the decision to slaughter animals at an older age, an increase in the number of older steers will cause the opportunity cost of feed to rise temporarily. This rise will induce a slight reduction in the rest of the herd, so that the net increase in the equilibrium herd as the result of the lower r is small. Moreover, the optimal feed input to each animal will be only slightly smaller than that when the discount rate was higher, so that most animals in the herd will continue to convert feed to beef at approximately the same rate as when the store of wealth effect did not exist.

The beef production decline caused by the store of wealth effect is determined by the differential growth of those older animals which would not have been included in the herd previously, versus that of the younger animals who are no longer maintained. The younger animals which are displaced will have an age distribution approximately equal to that of the herd in its original situation, i.e., some will have been nearly as old as the older steers retained. This moderates the effect even more. As an illustrative example, if the slaughter age of steers were extended from four to five years by a reduction in the discount rate from 8% to 4%, a rough calculation indicates that total beef production would decline by about 6%. I believe this figure significantly overstates the decline which may be expected in practice from the store-of-wealth effect.

Consider now the impact of communal ranges. The use of communal range lands in Swaziland alters the economic system so that several of the results which would occur with private range lands suffer important changes. With communal ranching, the cost of feed to the individual herder is zero. As there are few other inputs of economic importance, the cost of the input stream as a whole falls greatly. However, while the individual herder can add animals to the national herd at will, he has no control over the amount fed his animals.[2] The total feed available is given and must be shared equally among the animals in the herd, whatever their number. The result is an increase in the size of the herd, and a decrease in total beef production, as is explained in the following analysis.

Assume an initial situation with private range management in which the cost of feed represents its marginal productivity, with the livestock herd in respective equilibrium. Then, because of the implementation of a communal range instead of private lands, feed costs are reduced sharply for all herders. Assuming no change in the demand for beef, further investments in cattle will be privately attractive, the profitability of breeding calves having increased dramatically. The number of animals in the herd will increase. However, because the total forage available is fixed, efforts to increase the number of animals will lead to a decline in the feed available per animal. This is a situation of overgrazing, relative to private management, which will result in lower total output.[3]

The "simultaneous" reduction in the cost, and in the quantity, of feed will extend significantly the optimal age of slaughter. Under a private range system, $\hat{\theta}$ occurs where

$$\frac{(\dot{P w})}{P w} = r + \frac{C i}{P w}, \tag{1}$$

where w is the animal's weight.

Under a communal range system, however, where feed costs are zero, the growth of the animal's value during the year must cover only the interest rate. If the price of beef is not strongly dependent on age, the animal's value depends on its weight. Then, with a real interest rate of, say 8%, herders will find it profitable to hold an animal until its weight gain has slowed to this rate, which will occur close to physical maturity. Communal ranching also will lower the feed rations available individual animals, reducing their rate of growth throughout their lives

[2] The situation in Swaziland is thus described: "Rights to the use of communal resources, such as pasture land, woodland and water, are held communally and not exclusively. An individual is not confined to any particular area—for example, all Swazis are theoretically permitted to use grazing land anywhere in the country; in practice, each individual restricts his activities to areas accessible to the homestead. After harvest, plowed land with standing crop residues reverts back to communal use and the community grazes stock without hindrance" (IBRD).

[3] Overgrazing will decrease pasture quality through time, resulting in less total forage availability, not only less per animal. I ignore this problem in the discussion, though it is an issue of great importance.

and further extending their optimal age of slaughter.[4]

The only resource controlled by the individual herder in a system of communal ranges is the capital invested in the cattle he owns, whose return he seeks to maximize. His principal decisions concern whether to purchase animals or to sell, which affect the slaughter of mature animals and the production of calves. When aggregated across all herders, such decisions determine total herd size. The livestock sector is in equilibrium when the feed resources available each animal, given the price of beef, permit the internal return earned on the capital invested in animals to equal the market rate of interest.[5] In equilibrium, however, the competitive efforts of individual herders to extract value from the common range will have led to its overexploitation. The economic rent of rangelands will be totally dissipated and the value of production (assuming a perfectly elastic demand) will be reduced by this amount. This situation is akin to that which has been analyzed for fisheries (Gordon).

Because the commons problems induces a serious market distortion, a real welfare loss is involved and the beef production decline is much larger than that caused by the store-of-wealth effect. Without detailed information on the productivity of the range lands under proper control, it is impossible to estimate the beef decline precisely. However, judging from the relative values of land and cattle stocks in other countries having extensive range systems, the production loss could equal one-third.

Within the context of communal ranges, the marginal conditions yield a negative short-run slaughter response to price changes, as was the case under private range management. An increase in beef price will make cattle herding more profitable, inducing an increase in herd size. However, the net effect will be small. Contrary to the case of private range management, without collective action no increase in total feed resources will occur in response to a higher price. Any increase in herd size therefore will reduce further the average feed ration, resulting in yet lower herd technical efficiency. Therefore, although an increase in price will result in an increased value of total output, it will be small, and the quantum of marketed beef could actually decline.

Other effects of communal ranching may be mentioned briefly. The composition of the herd will reflect the low technical efficiency achieved; there will be a high proportion of cows because the weaning rate is low, and there will be a higher proportion of older steers because their slaughter age is advanced. Herd offtake will be low because only a low proportion of steers and cows will be slaughtered. Nearly all heifers will be required for replacement, so that a herd buildup, when desired, can be achieved only gradually. A significant proportion of the short-run response to prices is likely to be of the speculative type, with herders deciding to sell mature steers or withhold them for another year on the basis of future price expectations.

Climatic conditions and the use of unimproved pastures in Swaziland are likely to exacerbate the situation described above. These factors should cause a high seasonal variation in forage available per animal, which again is given to the individual herder. Animals will gain weight in a rachet-like manner; a significant proportion of what is gained in seasons of abundance will be lost in seasons of scarcity. An animal will require several years to reach adequate size, after which the producer will consider slaughter whenever there is sufficient forage for fattening. If forage is abundant in a particular year so that weight gain for large steers is good, producers will retain such animals longer than usual because their rate of growth will also have increased. When this period is ended, the animal will be sold.

DLK cite evidence of production inefficiency in Swaziland, attributing this to the store-of-wealth motive. Instead, I would attribute most of this inefficiency to the system of communal ranges. Consider the specific points mentioned by DLK.

First, DLK argue that Swazi cattle are sold at an older age than would occur if herders were interested in maximizing income. Detailed data are not presented, but they indicate that Swazi cattle are not sold until they have reached at least three years of age and that most cattle are marketed in excess of five years of age. However, for DLK to use the age of slaughter as support for the store-of-wealth hypothesis, they must show that it is not only high, but greater than the profit-maximizing age, given the conditions faced by individual Swazi herders including extensive grazing practices, unimproved pastures, and communal ranges. The latter factors have such important effects that there appears to be room for little impact from the store-of-wealth motive. For example, the reported slaughter ages are not so markedly different from those reported in Brazil and Uruguay, two countries which also use extensive grazing practices and which still have many unimproved pastures. In Brazil, as of 1970, steers were slaughtered between four and four and one-half years of age (Lattimore and Schuh). In Uruguay, two-thirds of the steers and 95% of the cows slaughtered exceeded three and one-half years of age in 1972–75 (Perez and Secco). A significant proportion of steers in Uruguay, those raised on poorer pastures in the north, are about five years old at slaughter. With otherwise equal conditions, but communal ranges, the slaughter ages in each of these countries would be extended.

Furthermore, the Swazi herd does not contain

[4] The lower feed ration also will lead to a higher age of first service for heifers, lower fertility rates for breeding animals, and higher mortality rates for the herd as a whole, relative to a system of private range management.

[5] I ignore the question whether, due to an absence of capital markets, there is a single market rate of interest.

Table 1. Swaziland Cattle Herd Composition—1975

Age	Swazi Owned		Non-Swazi Owned		Total
		(%)		(%)	
0–1 year males	31,387	7.4	8,590	9.8	39,997
0–1 year females	29,952	7.1	8,961	10.3	38,913
1–2 year males	31,837	7.5	8,111	9.3	39,984
1–2 year females	32,863	7.8	7,748	8.9	40,611
2–3 year males	44,936	10.6	6,943	8.0	51,879
2–3 year females	53,811	12.7	8,094	9.3	61,905
Cows	180,461	42.6	36,474	41.8	216,935
Bulls	18,074	4.3	2,372	2.7	20,446
Subtotal	423,321	100.0	87,293	100.0	510,614
Oxen	102,843		8,264		111,107
Total	526,164		95,557		621,721

Source: Ministry of Agriculture

such an unusually high percentage of older steers. Table 1 shows that male cattle two to three years old comprise 10.6% of the herd (oxen are excluded in making this calculation). The corresponding figure for the non-Swazi herd is 8.0%. The number of two- to three-year old males in the Swazi herd exceeds the number of one- to two-year-old males by 40%, suggesting that steers over three years are lumped into the two- to three-year category. But the difference mentioned suggests that steers older than three years account for only 3% of the herd. The impact of the store-of-wealth effect seems exaggerated after examination of these data.

The old age of slaughter in Swaziland may have another partial explanation. The Swazi herd contains a very large number of oxen, animals which differ from steers only by the fact that they have been trained to pull plows or carts. These animals, 20% of the herd, are kept until long after the optimum age of slaughter for beef production because they are needed for draft purposes. They are slaughtered when age causes their draft value to decline. If no distinction is made regarding steers and oxen at slaughter, the average age of slaughtered "steers" will be biased upwards, and producers will appear to have kept steers to an uneconomically old age when these actually will have been retained for draft purposes. Although some older steers also could be misclassified as oxen in the census figures, I doubt that this bias is as great.

Second, DLK indicate that overgrazing is the result of the store-of-wealth motive. I have argued that there is little evidence of the retention of older animals for this purpose, and that the overgrazing is doubtlessly the result of communal ranges, which would introduce a more uniform expansion of the herd.

Third, DLK indicate that the composition of the herd in Swaziland is unusually constant over the cattle cycle. They argue this would not occur if more females than males were withheld in response to price increases, and vice-versa, as they believe would take place if producers attempted to maximize incomes. However, a constancy in the herd is expected in Swaziland because of low technical efficiency, due again principally to the commons problem. In addition, because real cattle prices increased rapidly on several occasions, by 38% between 1964 and 1968 (8.4% per year) and by 36% between 1972 and 1975 (11% per year), short-run speculation probably induced herders to withhold steers to greater ages during these periods. This withholding also would tend to preserve the constancy of herd composition.

The Store of Wealth and the Negative Price Response of Slaughter

As mentioned earlier, DLK explain the negative price response of cattle slaughter by postulating a sale-for-specific-cash needs theory. This theory is consistent with their store-of-wealth argument, where cattle are treated as a "savings account" (p. 42). However, if cattle are sold only to meet herders' specific cash needs, one would expect aggregate cattle receipts to be fairly constant from one year to another.[6] This is not the case.

I estimated total herd receipts by multiplying the total Swazi herd (table 2) by DLK's offtake rate (to obtain the animals slaughtered), and multiplied this by DLK's real cattle price. The resulting series has a coefficient of variation of 0.39. However, the number of Swazi herders has increased during the period studied. To obtain a series which would better reflect per capita receipts, I deflated the total herd receipts by 2% per year, the rate of growth of Swazi population during the last decade. This series still has a coefficient of variation of 0.24, remarkably high for any index expected to represent variations in annual consumption expenditures at a national level.[7] However, the variation in slaughter

[6] The cash needs of individual producers might vary somewhat, but their aggregate expenses should be relatively stable.

[7] The coefficient of variation of the deflated cattle prices is 0.29.

Table 2. Swaziland Cattle Herd Census: 1950–75

Year	Swazi Owned	European Owned	Euro-African Owned	Totals
1975	526,164	85,722	9,835	621,721
1974	509,853	88,204	9,309	607,366
1973	499,340	86,536	16,538	602,414
1972	486,316	92,074	10,830	589,220
1971	468,150	92,319	11,316	571,785
1970	459,075	96,929	12,365	568,369
1969	437,567	90,319	10,334	538,220
1968	421,419	83,926	9,619	514,964
1967	410,084	85,081	9,358	504,523
1966	393,133	88,620	9,275	491,028
1965	403,860	96,631	9,594	510,085
1964	435,773	98,949	19,161	553,883
1963	416,717	104,721	10,102	531,540
1962[a]	411,733	106,149	10,205	528,087
1961[a]	406,823	107,595	10,309	524,727
1960	401,973	109,067	10,414	521,454
1959	388,688	104,921	10,306	503,915
1958	380,720	99,373	11,586	491,679
1957	355,659	98,351	9,009	463,019
1956	355,824	94,266	7,849	457,939
1955	333,631	88,862	8,852	431,345
1954	328,407	84,711	8,592	421,710
1953	326,985	85,566	8,111	420,662
1952	327,474	78,883	7,818	414,175
1951	327,964	72,722	7,536	408,222
1950	334,252	76,961	6,416	417,629

Source: Ministry of Agriculture
[a] Observations for these years have been estimated by geometric interpolation.

receipts is of the same order as those encountered in other commercial cattle sectors (Barros, Jarvis 1974 and 1977, Lattimore and Schuh, Nelson and Spreen, Rivas and Valdés), suggesting that producer response to changing cattle prices is a good explanation of this variation.

Another test of the cause of variation in slaughter can be obtained from the theory outlined above. Variations in the capital value of cattle, which would induce temporary and permanent variations in the rate of slaughter, can be brought about by variations in P, C, and r. A change in the demand for animals as a store of wealth would imply a change in the discount rate. In the short run, a higher demand could increase the "capital" value of animals, reflecting the increased value of the store of wealth service, and reduce slaughter. However, if Swaziland actually faces an elastic demand for the animals slaughtered, as DLK assert, a change in the store-of-wealth demand would not affect slaughter prices. And, because DLK have shown that changes in slaughter are highly correlated with changes in beef prices, it appears that it is the change in the latter, and not in the demand for a store of wealth (changes in r), that explains slaughter variation.

DLK also argue that the negative price response they encounter is different from that found in the other studies cited because "the response (in Swaziland) holds over a long period of time (27 years)." However, the price variable used by DLK in their regression analysis to explain changes in the rate of offtake has the long-term price trend removed. Thus, DLK are looking precisely at the effect of changes about the trend, or the cyclical changes. Their argument regarding the "long term" therefore seems invalid.

The Counterproductiveness of Livestock Development Programs

DLK assert that the livestock development programs being implemented in Swaziland in recent years are counterproductive. They argue that these programs have exacerbated rather than improved the overgrazing situation by stimulating producers to increase the number of animals owned for nonproductive purposes, resulting in a declining offtake rate for the herd.

I do not believe the evidence provided is conclusive. First, it is not clear that the offtake rate has

declined. Second, even if the offtake rate has declined in recent years, the herd extraction rate, which is a better index of technical efficiency, has risen.

The data in DLK's table 1 show that the choice of subperiods is crucial to any judgment regarding the offtake rate. The average offtake for the period 1954–61 is 8.93%, while that for 1968–76 is 8.90%. Save the exceptional period 1962–64 (and possibly 1965–67, for which no data are given), there is no obvious change in the offtake rate over the last twenty-three years.

The unusual increase in 1962–64 may have an explanation unrelated to technical efficiency. I suspect it is caused by Swazi herders having purchased animals from Europeans who were liquidating their herds (because of political uncertainty regarding the then impending Swaziland independence), fattening these animals and subsequently slaughtering them. Given that a large percentage of Swazi animals are kept for milk and draft purposes, a relatively small increase in animals kept and slaughtered for beef could cause the extraction rate to rise significantly. This argument also would explain why the extraction rate declined to normal levels after the European herd had stabilized. If this conjecture is valid, there has been no change in the offtake rate over time, when appropriately adjusted.

Regardless of the behavior of the offtake rate, the extraction rate (slaughter plus change in herd), which is a better indicator of technical efficiency because it includes the effect of herd variation, has risen over time. Data on the offtake rate, the average rate of herd increase, and their sum, the extraction rate, is shown in table 3. The offtake rate for 1950–64 appears higher than that for 1968–75, but much of this difference is due to the unusual rise in the extraction rate for 1962–64, already discussed. In any event, the offtake rate shows only one part of the picture. The high growth rate of the Swazi herd in the period 1968–75 meant that Swazi herders were making larger investments during this period, responding to higher prices, instead of sales. When these investments are taken into account, the extraction rate is seen to have risen in the more recent period.

This achievement is even more impressive when it is remembered that an expansion in herd size under a communal range system, as occurred following the large price increases after 1964, should have resulted in lower herd technical efficiency, including a lower extraction rate. The rapid herd expansion since 1969, without a significant decline in the extraction rate, reflects positively rather than negatively on the beef development programs implemented.

Conclusions

This paper does not suggest an absence of problems in the Swazi livestock sector, but rather questions what is the root of the low technical efficiency observed and the course of action by which the situation may be improved. DLK believe that Swazi herders maintain animals for purposes other than to produce beef, principally as a store of wealth, and are little motivated by market incentives. On the contrary, I believe that Swazi herders respond to market incentives similarly to cattle producers in other commercial livestock sectors, although I do not deny that cattle may serve as a store of wealth.

I have shown that the store-of-wealth effect is not inconsistent with a market orientation. Indeed, cattle must be valued for their beef if they also are to serve as a store of wealth. More important, it easily is shown that any economic incentive to encourage beef production will have the desired effect whether or not the store-of-wealth effect exists. Thus, conventional livestock development programs will be effective when animals are held as a store-of-wealth.

If Swazi herders are not market-oriented, however, neither higher prices, improved pastures, government fattening ranches, nor even the establishment of private ranges will lead to increased production. The introduction of administrative controls from outside the sector would be necessary to achieve higher production, not simply to limit herd size, but to govern all aspects of herd reproduction, maintenance, and slaughter. The motivation of Swazi herders is thus important, being fundamental to the design of government livestock policy.

It is perhaps surprising, given our differences in the analysis of the problem, that DLK's final policy prescription is similar to mine in at least one important respect. This similarity occurs, however, because their recommendation is inconsistent with their analysis. DLK concludes that Swaziland needs measures either to induce herders to sell more cattle (by increasing herders' cash needs or

Table 3. Period Averages from the Offtake and Extraction Rates

Year	(1) Average Offtake Rate	(2) Rate of Herd Increase	(3) Extraction Rate
1950–64	10.0	1.8	11.8
1950–61	9.5	1.8	11.3
1968–75	8.9	3.2	12.1

Source: Column 1, DLK, table 1; Column 2, calculated from table 2; Column 3 equals Column 1 + Column 2.

by reducing the relative attractiveness of cattle as a store of wealth), or to force herders to reduce cattle numbers by administrative fiat. Having posed these alternatives, DLK state that it is unrealistic to expect by changing land tenure to decrease herders' desire to hold cattle as a wealth store, and DLK fall back on administrative control of cattle numbers as the solution. Of the policies DLK consider, however, only the increase in the availability of alternative assets is appropriate if the store-of-wealth demand for cattle is important. The administrative control of cattle numbers would not be suitable. Because the store-of-wealth effect introduces no market distortion, the use of administrative controls to bring herd size below the level desired by producers would reduce, not increase, total sectoral welfare.

A permit system is appropriate as a solution for a common range system, however. In this situation, some change in the assignment of grazing rights is needed. The subdivision of the range for private use is the economically preferred policy, but it appears to be politically unfeasible in the intermediate run. The implementation of direct controls on the number of animals which individual herders will be permitted to graze is the next best solution. Thus, although DLK and I differ in our diagnosis of the problems facing the Swazi livestock sector, we agree on this aspect of the solution.[8]

This leaves only one aspect of the livestock development programs to be discussed. Although private initiative will be constrained sharply until a solution to the common range problem is found, the livestock development programs initiated in recent years include some policies which should be beneficial in the meantime. I refer particularly to the establishment of government breeding and fattening ranches which permit strict herd control within their boundaries. These ranches will increase output and also should demonstrate the attractiveness of private feed stocks. This demonstration may induce Swazi herders to accept private range allocations or permit systems more willingly in the future.

[8] The precise design of the control system is outside the scope of this comment, but I believe it should allow as much room for individual initiative as possible, perhaps by permitting herders to purchase and sell permits, once issued.

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References

Barros, M. César. "Respuesta de la producción bovina ante cambios de precios: Un enfoque econométrico." *Trabajos de Investigación.* Departamento de Economiá No. 8, Universidad Católico de Chile, Nov. 1973.

Doran, M. H., A. R. C. Low, and R. L. Kemp. "Cattle As a Store of Wealth in Swaziland: Implications for Livestock Development and Overgrazing in Eastern and Southern Africa." *Amer. J. Agr. Econ.* 61(1979):41–47.

Gordon, H. Scott. "The Theory of a Common Property Resource." *J. Polit. Econ.* 62(1954):124–42.

International Bank for Reconstruction and Development (IBRD). *Swaziland Rural Development Project Appraisal Report.* Washington, D.C., Jan. 1977.

Jarvis, Lovell S. "Cattle As Capital Goods and Ranchers As Portfolio Managers: An Application to the Argentine Cattle Sector." *J. Polit. Econ.* 82(1974):489–520.

———. "The Economic Determinants of Uruguayan Beef Cattle Herd and Slaughter Levels, 1960–76." Processed. Plan Agropecuario, Ministry of Agriculture and Fisheries, Uruguay, Aug. 1977.

Lattimore, Ralph G., and G. Edward Schuh. "Endogenous Policy Determination: The Case of the Brazilian Beef Sector." *Can. J. Agr. Econ.* 27(1979):1–16.

Nelson, Glenn, and Thomas Spreen. "Monthly Steer and Heifer Supply." *Amer. J. Agr. Econ.* 60(1978):117–25.

Pérez A., Carlos, and Joaquín Secco G. "Uruguay: Una caracterización del sector productor de carne vacuna." Cali, Colombia: Center for Research in Tropical Agriculture (CIAT), 1977.

Rivas, L., and A. Valdés. "Variaciones de las existencias y ventas de ganada en Colombia durante 1940–70: un enfoque econométrico." *Revista de Planeación y Desarrollo* 10(1978):49–82.

Cattle As a Store of Wealth in Swaziland: Reply

A. R. C. Low, R. L. Kemp, and M. H. Doran

Jarvis believes that there are four main differences between us.[1] He maintains that: (*a*) whereas we believe that the store-of-wealth effect seriously reduces beef production, he attributes the poor technical efficiency observed in Swaziland much more to the existence of communal ranges; (*b*) whereas we believe that the negative price response of cattle slaughter is consistent with noncommercial attitudes, he believes it is more likely to be evidence that they are responsive to market incentives; (*c*) whereas we hold that Swazi herders exhibit a negative price response because they maintain cattle as a store of wealth and only sell to meet specific cash needs, he maintains that Swazi herders' decisions to sell are based on the profit-maximizing motive; and (*d*) whereas we believe that recent livestock development programs may exacerbate the overgrazing problem and thereby reduce technical efficiency, he does not believe that technical efficiency has fallen and believes that the livestock projects have had a positive effect.

In this reply, we accept his argument in respect of point (*a*), agree that the position he adopts in respect of point (*b*) is as valid as ours, but continue to disagree with him on points (*c*) and (*d*).

The Comparative Effects of the Store-of-Wealth Motive and Communal Grazing on Technical Efficiency

We accept Jarvis' criticism of our original analysis in respect of the evidence we provided for the store-of-wealth hypothesis which also can be explained in terms of the communal grazing system. In the light of Jarvis' comments, we agree that the advanced age of slaughter and constant herd composition do not provide convincing evidence that Swazis keep cattle as a store of wealth.

The authors are currently working in the Ministry of Agriculture, Swaziland. M. H. Doran is an agricultural economist supported by the Australian Development Assistance Bureau. A. R. C. Low is a Ministry of Overseas Development (U.K.) agricultural economist, and R. L. Kemp is a computer programmer supported by U.S. AID. The authors alone are responsible for the views expressed here and the interpretation of the data presented.

[1] There are a number of details in Jarvis's comment with which we would take issue. The exclusion of oxen in the examination of herd structure is one. The suggestion that Swazis bought European-owned cattle and fattened and slaughtered them in 1964 is another. These are not the only passages that demonstrate a lack of understanding of the Swaziland situation. Because we do not comment on them, they should not be taken as being accepted by us. We are concerned to focus on what seem to us to be the major issues of general relevance and interest rather than argue about specific details.

The Meaning of the Negative Price Response

Similarly, since a negative short-term price response is equally consistent with the store-of-wealth and profit-maximising motives, it cannot be used, in itself, to support the store-of-wealth hypothesis. Low already has stressed the weakness of using price response data to argue for or against the commercial motivation of traditional cattleowners.

The Reason for the Negative Price Response

We cannot accept Jarvis' rejection of our explanation for the observed negative price response based on our sale-for-specific-cash-needs theory. Jarvis bases his rejection on the fact that the estimated cattle slaughter receipts have not been constant from one year to another as one would expect if cattle are sold only to meet herders' specific cash needs. But herders' cash needs from cattle sales are not constant from one year to the next. They vary according to annual changes in cash supply received from other income-earning opportunities as well as changes in cash needs, particularly for the purchase of food, depending on the previous season's maize harvest.

We have related annual variations in cash needs and cash supply to cattle sales in a cash needs/supply model described in detail elsewhere (Low, Kemp, Doran). The estimated linear regression equation was

$$\underset{(6.1)^*}{Y = 6.0} + \underset{(4.0)^*}{7.5X_1} + \underset{(3.1)^*}{0.1X_2} - \underset{(-3.9)^*}{0.4X_3},$$

where Y is the estimated offtake rate from the Swazi herd; X_1, the Swazi human population relative to the value of the Swazi cattle herd; X_2, the seasonal cash need (reflected in low rainfall and poor harvests in the previous season) relative to the value of the Swazi cattle herd; and X_3, the annual earnings from mine employment relative to the value of the Swazi herd. R^2 is the coefficient of determination. The coefficient of determination corrected for degrees of freedom, $\bar{R}^2$, was .68; the Durbin-Watson statistic 1.19, the F-statistic for the regression, 18.4, and finally, the asterisks denote t-ratios, significant at the .01 level.

Thus, if the growth of the human population or the increase in the need to purchase food requirements are greater than the increase in the value of the cattle herd, the rate of offtake will increase. But an increase in alternative cash incomes relative to

Table 1. Average Herd Sales Rates (%)

	All Regions	High Veld	Middle Veld	Low Veld
All herds	4.3	3.6	3.5	7.9
—herds of 1–17 head	4.3	3.9	3.6	11.1
—herds of 18+ head	4.3	1.8	3.2	6.8

Note: Own-slaughter rate averaged 4.6% over all herds, giving an offtake rate of 8.9%.

the value of the cattle herd will result in a reduced rate of offtake. Cash receipts from cattle sales can therefore be expected to increase over time as the human population grows, as well as to exhibit annual variations according to the success of the previous season's food harvest and the level of alternative cash income earned.

The point is that receipts from cattle sales are not equivalent to annual consumption expenditures. They represent the balance of expenditures that cannot be met from alternative sources (wages or own-food production). Thus, a variation in receipts from cattle sales is entirely consistent with the store-of-wealth motive and we are able to explain 70% of the observed annual variation in these terms.

Further evidence for the sale-for-specific-cash-needs hypothesis has been obtained in a recent cross-sectional cattle-marketing survey. The results of this survey indicate that sales rates among Swazi cattle herds vary considerably according to their size and the ecological region in which they are herded (Low and Fowler). Table 1 shows that sales rates are higher in the lowveld than in the high or middlevelds and that, within these regions, sales rates are higher in smaller herds than larger ones. These observations can be explained in terms of households' different levels of cash needs from cattle sales relative to the value of the herd owned. In the lowveld, cash needs are greater than in other regions because crop yields, especially of maize—the staple food—are much lower and because wage-earning opportunities are not so good. Thus, even though lowveld households own larger herds than others, their sales rates are higher. Within regions, the cash needs of households can be expected to be relatively constant, and thus households with larger herds will have a smaller sales rate.[2]

The Effect of Production-Orientated Development Programs on Technical Efficiency

Jarvis presents data to show that the average extraction rate between 1950 and 1964 is lower than it was between 1968 and 1975. He argues from this that the livestock development programs enacted during the latter period have had a positive effect on technical efficiency because he would otherwise have expected the extraordinary price rise since 1968 to have resulted in reduced offtakes, higher stocking rates, and lower technical efficiency. This reasoning leads him to challenge our suggestion that the recently enacted production-oriented development programs may be counterproductive, and suggest, instead, that they may be a second best alternative, while direct grazing controls remain politically unpalatable.

We cannot accept this line of argument because it is inconsistent with both the available data on technical efficiency and with Jarvis' own theoretical analysis. Figure 1 shows how the extraction, calving, and overall death rates have varied between 1954 and 1977.[3] Multiple linear regression analysis

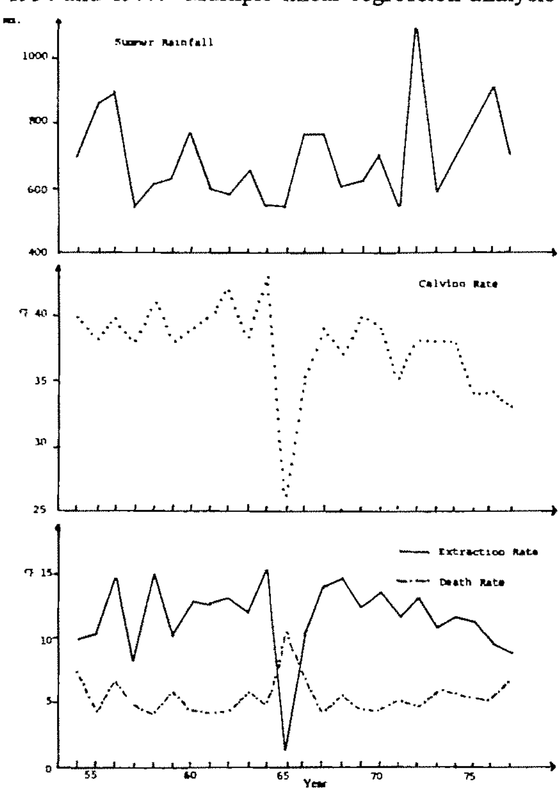

Figure 1. Rainfall and cattle data

[2] Household size is relatively constant compared to variations in the size of herds owned.

[3] Calving rate is defined as the number of 0–1 year olds as a percentage of cows at the annual census. It therefore includes the 0–1 year old death rate. No aggregate data on the number of calves born is available.

suggests that 70% of the annual variation in the extraction rate between 1954 and 1977 can be explained in terms of the calving and the overall death rates. These parameters exhibit different trends before and after the 1964/5 drought-cum-foot-and-mouth years (see table 2). Prior to 1964/5 calving rate appeared to be on the increase and death rate to be falling, although the trends are not statistically significant. This resulted in a significant positive trend in the extraction rate between 1950 and 1964. Between 1967 and 1977, the picture is different. Calving rate has exhibited a significant negative trend, while there has been a significant positive trend in the death rate. The result has been a highly significant downward trend in the extraction rate over the period.

Jarvis's presentation of the data is therefore misleading. While the average extraction rate for the 1950–64 period is marginally lower than that for 1968–75, it was on the increase in the former period and has been on the decrease since 1967. Furthermore, the decrease occurs in the period in which the substantial investment in production-increasing programs took place (from 1973).

As there has been no significant downward trend in rainfall between 1967 and 1977, we conclude that increasing grazing pressure is the main cause of the decreasing trend in technical efficiency over this period. Jarvis suggests that the increased grazing pressure has come about as a result of the recent substantial increases in the price of cattle. We would agree with him that the increasing value of cattle has induced herders to reduce their offtake rates (although we differ on their motives for doing so). But we do not agree with his suggestion that recent production improvement programs have had a positive effect sufficient to compensate for the negative effect of the price increase. Nor do we understand why he expects otherwise, since production improvements work in the same direction as price increases: they increase the growth of the value of cattle between one time period and the next.[4]

Jarvis seems to be inconsistent in expecting technical efficiency to increase as a result of production-improving measures when he accepts that price increases will reduce technical efficiency.[5] It is concievable that productivity improvements may be sufficiently large in the short term to counteract their immediate efficiency-reducing effect through increased grazing pressure. But, since they will result in an increase in grazing pressure over time greater than it would otherwise have been and, since increasing grazing pressure will reduce the impact of the production-improving measures on technical efficiency, productivity improvements eventually will be self-defeating. Where overgrazing exists, and in the absence of direct control on the numbers of animals which individual herders will be permitted to graze, it is illogical to expect production improvement measures to result in a lasting increase in the level of technical efficiency. This reasoning holds whether cattleowners are believed to behave according to the profit or the store-of-wealth motive.

Conclusion

Although Jarvis has some justification for challenging our assertions on the basis of the evidence we provided in our original article, we believe that the

[4] We would not go so far as to suggest that the production improvement programs have, as yet, contributed significantly to the decrease in technical efficiency. They have not yet been extended widely enough or for long enough to have had such an impact.

[5] Jarvis accuses us of inconsistency in suggesting that changing land tenure will not decrease herders' desire to hold cattle as a store of wealth. We suggest no such thing. We argue that a change to private land ownership will reduce the store-of-wealth motive but reject it as a feasible policy alternative under the current political climate.

Table 2. Trends in Technical Efficiency Parameters and Rainfall

	Extraction Rate (%)	Calving Rate (%)	Death Rate (%)	Summer Rainfall (mm.)
1950–1964				
Slope	0.32			
Intercept	9.10			
Corr. coefficient	.59**			
1954–1964				
Slope	0.33	0.21	−0.12	−14.06
Intercept	10.30	38.47	5.84	766.94
Corr. coefficient	.45	.40	.36	.40
1967–1977				
Slope	−0.51	−0.54	0.18	9.39
Intercept	15.00	40.04	4.16	671.08
Corr. coefficient	.91**	.74*	.73*	.22

Note: The ** denotes significance at the .01 level; * denotes significance at the .05 level.

additional evidence provided here reinforces the main contentions of our paper. These are that (*a*) Swazi cattleowners hold cattle as a store of wealth and sell mainly to meet specific cash needs, and (*b*) production-oriented development programs in Swaziland can be expected to be counterproductive in the absence of a change in the land tenure system or effective grazing controls.

Our understanding of Jarvis' analysis leads us to the conclusion that (*b*) does not depend on (*a*) and remains valid even if Swazi cattleowners keep cattle mainly to produce beef. Thus we do not agree that production-oriented development programs are second-best alternatives in the absence of a definitive solution to the communal grazing problem. To suggest that they might be is dangerous because it enables planners and politicians to evade the real and difficult issues (of grazing control or land tenure changes) by promising that improved productivity, of itself, will lead to an increase in technical efficiency and alleviate the overgrazing problem.

The significance of the store-of-wealth (sale-for-specific-cash-needs) motivation is that, where it pertains, cattle development programs cannot be considered sensibly in isolation from other household activities such as food or cash cropping and off-farm wage employment. Developments in these other fields will crucially affect cattle offtake rates and have longer-term repercussions on technical efficiency and overgrazing.

Jarvis and we agree that the definitive solution would be to change the tenure system to one of private rather than communal control of the range. This would reduce the desire to hold cattle as a store of wealth and would result in an increase in technical efficiency as Jarvis indicates. But this is a political issue which aid donors and planners cannot directly overcome. They can only provide technical assistance in the form of conventional production development programs. The question we pose is: can these production-oriented programs have a lasting positive impact on technical efficiency and production in countries such as Swaziland, while the political problems remain unresolved? We think not; Jarvis seems to think otherwise.

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References

Low, A. R. C. "The Estimation and Interpretation of Pastoralists' Price Responsiveness." London: Overseas Development Institute Agricultural Administration Unit Pastoral Network Pap. Series 10, 1980.

Low, A. R. C., and M. H. Fowler. "The Effect of Ecological Region and Herd Size on Cattle Offtake Rates." Monitoring and Evaluation Study No. 4, Preliminary Rep. No. 1, mimeograph Ministry of Agriculture, Swaziland.

Low, A. R. C., R. L. Kemp, and M. H. Doran. "Cattle Wealth and Cash Needs in Swaziland: Price Response and Rural Development Implications." *J. Agr. Econ.* May 1980.

Editorial Notice

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V. James Rhodes
Editor

Books Reviewed

Duft, Kenneth D. ***Principles of Management in Agribusiness.*** **Reston, Va.: Reston Publishing Co., 1979, x + 470 pp., $15.95.**

The author has attempted to provide a textbook containing the principles of management for nonfarm agricultural enterprises. He states that it is directed at second- and third-year college students enrolled in an introductory agribusiness management course. The book is divided into nine chapters, beginning with an introduction to agribusiness and the evolution of basic managerial principles. Chapter 3 deals with personnel and employee relations and includes sections on alternative supervisory styles and effective communications. Chapters about basic accounting concepts and financial management are followed by long-range planning. The last three chapters of the book contain a conglomerate of topics on operational challenges for management, organization and management theories, inflation, energy, and farmer cooperatives.

The book reads well at a level appropriate for second- and third-year college students. However, much of the content seems to be directed toward established agribusiness managers. Many of the topics included in personnel, finance, and operational challenges to management appear to focus more on the "fine-tuning" dimensions rather than the basics of agribusiness management.

Of more serious concern are those topics omitted in the text that should be included in an introductory agribusiness management course. These topics would include: a discussion of the traditional fixed and variable costs and the cost categories relevant for decision making, such as incremental, opportunity and semivariable costs, the role of the Small Business Administration (SBA), the impact of government regulations, and product or service marketing.

The book contains a good discussion of pricing techniques and advertising strategies. Topics on managerial marketing strategies, such as sales forecasting and channels of distributions and logistics, should be included in an introductory course.

Another concern deals with the organization of the book. Unrelated topics appear in several of the chapters. For example, chapter 8, "Managerial Methodology," contains a discussion of management by objective but also includes inventory control methods.

The basic financial accounting statements of the firm and the more commonly used financial ratios are well-described. A good explanation of breakeven analysis as a financial-planning strategy also is provided.

Few textbooks are available for introductory agribusiness management courses. This book contains many of the topics that should be covered in an introductory course. It will, however, require the use of supplemental material, particularly in the areas of production costs and marketing concepts, policies, and strategies, if it is used as the primary text in an introductory agribusiness management course.

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Healy, Robert G., and John S. Rossenberg. ***Land Use and the States,*** **2nd. ed. Baltimore, Md.: Johns Hopkins University Press for Resources for the Future, 1979, xvi + 284 pp., $18.00, $4.95 paper.**

The nationwide momentum for an increased public role in land use management probably reached its peak in the early 1970s. Yet land use remains an important social issue and is prominent on the legislative agenda in many states and municipalities. There also seems to be a greater level of maturity in the thinking of policy makers and the public about land use management. There is now a general recognition that the problems encompassed by this topic are enduring, require a continuing analytical effort, and involve difficult social choices.

The increased role of state government in land use decisions, an important development in the evolution of land use policy in the United States, is the subject of the book under review. Robert G. Healy and John S. Rosenberg have revised and updated Healy's original book (published in 1976). The objectives of the book are to develop the rationale for increased state involvement in controling the use of privately owned land, to compare and evaluate some of the most significant statewide land-use policy experiments, and to explore the bounds for a successful state-local partnership in land-use control.

This book contains eight chapters. The first two chapters document the diverse nature of land-use conflicts and present the theoretical basis for questioning whether the responsibility for implementing land-use policy is best left entirely to local government. This presentation makes it very clear why states have begun to take back some of the land-use control authority that historically has been delegated to local governments.

In chapters 3, 4, and 5, Healy and Rosenberg present a detailed examination of the actual implementation experience with three major state land-use programs adopted in the early 1970s—Vermont's Act 250, the California Coastal Zone Conservation Act, and the Florida Environmental Land and Water Management Act. Each of these

programs was adopted in response to unique land-use problems in each state. These case studies are particularly useful for developing an understanding of what a state role in land-use policy can and cannot accomplish. Beyond this the case studies illustrate that there is a big difference between abstract analysis of program structure and the laborious task of describing and analyzing program functioning and performance.

In the last three chapters, the authors examine the implications of the case studies for a state role in land-use control. They identify the kinds of land uses for which a state role in land-use control is appropriate, describe the alternative ways in which the state can influence land-use decisions, explore the issues (economic, political, and social) raised by state regulation, and outline the elements of an effective state land-use control program.

This book is rich with examples of land-use conflict. It provides an excellent overview of land-use problems and some of the public policy responses at the state level. It seems safe to say, however, that many analysts will argue with some of Healy and Rosenberg's conclusions. Particularly provocative is their recommendation that the adoption of land-use controls should not await the completion of comprehensive land-use plans. While many may disagree, the experience with statewide land-use policy in this country provides considerable evidence in support of a regulate first-plan later approach.

This book will be useful to land-use policy makers, land-use planners, and citizen activists. Many economists may be disappointed by the absence of a well-developed analytical framework for evaluating the effectiveness of land-use programs. In addition, the economic content of the book is neither comprehensive nor rigorous. Extensive footnote references partially compensate for the fact that detailed analysis of the economic impacts of land-use controls is beyond the scope of a book directed at a broad audience. Despite these limitations, this book is important background material for resource economists with research or teaching responsibilities in land-use policy.

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Hillman, Jimmye S. *Nontariff Agricultural Trade Barriers*. Lincoln, Ne., and London: University of Nebraska Press, xv + 236 pp., $13.50.

Agricultural trade and trade policy have been receiving increasing attention in recent years. This book provides the student of this subject a well-written and scholarly addition to the literature. The book does not pioneer new analytical approaches, nor does the author originate new hypotheses or evidence on the subject, but he does not claim this to have been his objective. Rather, its value lies in describing and backgrounding an important problem area that complicates the conduct of agricultural trade and trade negotiations. Beyond this, it also adds historical and geopolitical perspective on why trade impediments are devised and why they are difficult to dismantle.

Jimmye S. Hillman's work is a descriptive case study of how nontariff measures are employed by the major trading nations to insulate their domestic producers from the pressures and vagaries of competition. It is noted that while some success has been made in removing or reducing traditional specific and ad valorem tariffs as protective instruments, a decline in the general level of protectionism in the world agricultural trade arena is not a corollary result. Nontariff barriers have replaced tariffs as the most important means of impeding international agricultural trade. These instruments exist in a variety of forms including import quotas, restrictive licensing, variable levies, voluntary restraint agreements, mixing regulations, foreign exchange controls, border taxes, export subsides, sanitary and health regulations, packaging and labeling regulations, state trading, export controls, and other measures that interfere with trade flows and responses to market signals that would occur in their absence. The use of these various measures is inventoried in the book for a cross-section of selected countries with the useful result that the reader gains a better perspective of just how pervasive these devices are. A case study of the use of nontariff barriers in the red meat industry illustrates this point in even more vivid detail. The book closes with a final chapter devoted to issues that Hillman considers fundamental to the negotiation of nontariff barriers. The reviewer came away from this section with the feeling that it would have been much more effective if it had arrived in print in the earlier phases of the Tokyo Round of multilateral trade negotiations which are now completed. Nevertheless Hillman states the issues well and they will be relevant to future negotiations of nontariff barriers once they are updated by the lessons learned and for events that occurred in this last major round of trade negotiations.

Hillman eloquently presents the reminder that domestic farm policies are often the genesis of restrictions in international commerce of farm products. He observes correctly that nontariff measures are more complicated to deal with than traditional customs measures. He casts the subject into historical perspective and warns that ignoring the impact of domestic policies buttressed by nontariff instruments could increase the likelihood of a breakdown in international trade such as the one witnessed in the 1930s. The forte of Hillman's work is possibly the forceful and convincing way that he utilizes the King's English to state such points. Among our colleagues, one is seldom accustomed to such eloquence as he commands.

Hillman's book is not, of course, to be considered to be a complete and final treatment on the subject of nontariff agricultural trade restrictions.

To bring nontariff barriers into international negotiations, the level and extent of protection and distortion created by these devices need to be identified and documented. This work is a step in that direction to the extent that it chronologizes the evolution and describes the characteristics of nontariff restrictions in agricultural trade. However, no new analytical or empirical avenues to measuring the level of protection or the consequences of specific nontariff barriers upon consumer welfare and production and marketing efficiency are developed. Consequently, those looking for a rigorous analytical treatment of the subject will be disappointed. However, it is unfair to criticize the study on this basis. It still performs the useful function of inventorying and describing restrictive agricultural trade instruments and articulates the importance of the subject in such a forceful manner that it may well stimulate other investigators to plow the subject matter further.

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Hite, James C. ***Room and Situation: The Political Economy of Land-Use Policy*****. Chicago: Nelson-Hall, 1979, x + 340 pp., $18.95, $9.95 paper.**

James Hite provides a comprehensive survey of land-use policy in the United States. The approach is that of institutional analysis. The focus is land-use policy in urban areas. The treatment is broad; Hite introduces the historical, ideological, political, and economic aspects of public policies affecting the use of land. Chapters also are devoted to expenditure and revenue policies as these affect land use, and the author considers implications for planning posed by levels of and changes in information, knowledge, and technology.

Citizens interested in and concerned about land-use policy in this country are the intended audience for this book. The author does an excellent job of organizing and presenting diverse and complicated materials for this audience. Theory and concepts that might seem dry in another context are blended with history, quotes, examples, and current issues to form a rich and palatable blend.

Room and Situation also would serve well as the principal text in an undergraduate course with a multi-disciplinary approach to land use. Within each discipline, individuals can find points of contention and will not learn a great deal more about land use as approached within their discipline. But perspectives also may be broadened significantly by exposure to approaches outside their own discipline.

Planners may find *Room and Situation* both interesting and provocative. Such professionals would not learn new approaches to planning. Rather, Hite's analysis of the political roles and political tactics of planners might be of interest to such an audience. This analysis strips away certain mystiques surrounding planning and planners. Hence, professional planners may find the work provocative.

The incorporation of political analysis in the approach to studying land-use policy is a major strength and distinguishing characteristic of *Room and Situation*. Political analysis is used in two ways. Models and concepts from political science are applied to foster understanding of the current situation; that is, to explain the types of land-use policies we have and those that we do not have. Concepts of politics also are brought to bear on the often overlooked task of analyzing how particular abstract proposals might actually evolve if made subjects of public policy. The concepts and models from political science are diverse, drawing from one thread or another as appropriate to the subject being considered. The public choice approach is given considerable emphasis in a concluding chapter.

Analysis of the roles of information and knowledge in land-use policy and land-use politics is another strong point of this text. The author notes problems created by both the paucity and abundance of information and knowledge in areas related to land use. Also analyzed are the ways in which control of information is both a source of power and a factor that must be considered in understanding the shape and direction of land-use policy.

Athough the book strongly emphasizes the description and understanding of land-use policy, the author does consider some prescriptions for problems identified in the analysis. Among other prescriptions, the author gives most attention to the need to make information about land use widely available at low cost in order to allow citizens to participate in the formulation of land-use policy. The author describes how such an information system might be developed and reports on recent experiments with such systems. Here, the author falters in his otherwise superb application of political concepts to the understanding of public policy. When providing goods, a political system seeks information not only on what individuals want, but how badly they want it. One way in which the latter type of information is conveyed is through logrolling. That process is superbly developed by the author. Another way in which a political system measures how badly people want something is by making participation costly. Just as for private goods, intensity of preferences or demand is measured—albeit crudely—by how much people are willing to pay. Hite's proposal would significantly subsidize major costs of political participation. The author does not consider implications of his prescription for efficient allocation of publicly provided goods and for the needs of decision makers for information on salience needed to retain political support. Subsidization of the costs of participation may be defended on egalitarian principles. Perhaps the author would judge that such benefits outweigh disadvantages. But we do not know

because the political functions of costly participation are not considered by the author.

Such lapses are to be expected in a book with such a broad scope. The text remains an excellent introduction to land-use policy for citizens and students seeking a broad, highly readable, and carefully developed understanding of urban land-use policy in the United States.

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Hutchinson, T. W. *Review of Knowledge and Ignorance in Economics.* Chicago: University of Chicago Press, 1977, 186 pp., $5.50 paper.

This little book consists of an introduction, three chapters, and an appendix. On casual inspection a methodological treatise on knowledge and ignorance in economics might not appear to be of great relevance to agricultural economists. But a thoughtful reading will benefit almost any applied economist, although it must be emphasized the book will be of value only if it is read with reflection and introspection with respect to one's own thought processes. It will not yield dividends to the person who is seeking a "quick fix" methodology of economics. Many of us as agricultural economists have committed the errors that Hutchinson warns about and it is, therefore, most appropriate that it be reviewed in this *Journal*. The prospective reader should be aware that some passages will be meaningful only if the reader is familiar or is willing to become familiar with some of the recent literature on the methodology of science. The remainder of the book will be accessible to anyone having familiarity with theoretical and applied economic literature.

The introduction argues that the most dangerous kind of ignorance is that regarding the limits and limitations of one's knowledge. The author believes that ignorance of this kind on the part of economists will result in their causing noneconomists to have excessive expectations regarding the value of economic studies. The consequence is "disappointment and disillusionment" (p. 5) by those who have been led to believe economics can deliver more than it is capable of delivering. The introduction ends with some thoughts on graduate training and an approving quote from Jacob Viner to the effect that good teachers at the college level will never come from those who have been trained to think only within the limits of one subject or from the point of view of one subject.

Chapter two deals with prediction. Hutchinson accepts the notion that a principal aim of economics is to improve prediction; and that it is, to some limited extent, a feasible aim. As one might expect, the author moves quickly to deal with the methodology of science which has become associated with Sir Karl Popper. It is, of course, Popper's belief that the criterion for judging a science is its predictability, its capacity to "forbid" something from happening. Only in this way can conjectures be made that are capable of refutation. Hutchinson contrasts Popper's position to the argument advanced by Theil, which seems to concede that "scientific" prediction in economics and econometrics is not possible. The author takes a position intermediate between that of Popper and Theil. He believes that most predictions in economics are extrapolations of trends or deductions based on trends. Even though such a procedure has obvious weaknesses, Hutchinson believes that economists have no alternative. He argues, but does not document, that quite naive extrapolation in some cases has been shown to be superior to more elaborate deductive model building. The conclusion is reached that attempts to make economics "scientific" by reliance on mathematical model building is a methodological "dry hole" because any prediction must be based on trends, and trends will never provide the necessary completeness for a theory which will have the capacity to "forbid" events. This methodological discussion is followed by a discourse on whether predictions in economics are improving or not. Without attempting to summarize all of this discussion, one factor working to improve prediction is the availability of more accurate and current statistics; a factor working in the opposite direction is the increased complexity of modern economies.

Chapter three on the history and philosophy of science and economics permits the author to relate the viewpoints of Kuhn and other recent writers on the philosophy of science to those of Popper. Hutchinson speaks approvingly of attempts to understand the history of science. He warns, however, that there is danger that normative-positive confusion can develop easily, as it did with many in their interpretation of Kuhn. He also warns that different sciences have different histories, and this must be expected since they have different materials with which they must work. He says the labels "mature" and "immature" sciences are misleading because they lead to expectations that eventually the "immature" sciences will be comparable to the "mature" sciences. (Kenneth E. Boulding believes that "secure" and "insecure" would be better adjectives. See "Science, Our Common Heritage," *Science* 22 February 1980, volume 207, no. 4433.) He does not believe that economics can ever be like physics, but he does believe the rigor developed by the philosophers of science in advancing what constitutes "good" scientific procedure can be used in economics to prevent economists from becoming excessively dogmatic in the advice they extend to policy makers. Hutchinson presents examples of policy advice by economists where the methodological limits of economics have either been ignored or improperly observed.

Chapter four is concerned with the crisis of abstraction in economics. Hutchinson thinks the

stakes are high because he believes that economics can make a contribution to the maintenance of freedom by that which it contributes to the standards of discussion. If economics becomes more and more irrelevant to the real problems of the world because of excessive abstraction, its contribution to freedom will decline in a corresponding fashion and, if freedom dies, so will economics according to the author. He deplores the virtual absence of history in the study of economics at the present time and believes that a greater familiarity with past events would tend to discourage the excessive abstraction which results in irrelevant and unrealistic theoretical treatments of economic problems.

It is a pleasure to recommend this book. As noted, it contains much of value to any applied economist but it will be of special interest to the teacher and student of research methodology in economics.

Emery N. Castle
Resources for the Future

McCoy, John H. *Livestock and Meat Marketing*, 2nd ed. Westport, Conn.: 1979, AVI Publishing Co., x + 479 pp., $26.50.

The second edition of *Livestock and Meat Marketing* reflects the maturity and soundness of McCoy's important initial contribution to livestock marketing. His applied approach, intended for undergraduate programs and as a reference for graduate students interested in livestock and meat marketing, gives both the instructor and student a firm base upon which to build an individualized class.

McCoy has chosen neither to add nor to delete any of his initial sixteen chapters of the first edition. However, within several chapters, the discussion has been either expanded or contracted to reflect the dynamics of developments within the changing livestock industry. Of course, the numerous tables and charts were updated to reflected 1977–78 published data, where available.

The first five chapters, which deal with the historical perspective of livestock marketing, economic theory and principles, and production and consumption, are unchanged from the first edition. This section is fraught with the problem of covering microtheory in 100 pages. However, the important elements needed for further analysis at least are introduced.

Chapters 6 through 9 describe the institutions that perform several marketing and pricing functions in livestock and meat marketing. Many analysts of the industry would agree that substantial changes have occurred, and are occurring, in the structure of the meat-packing industry. McCoy has chosen throughout the book to ignore, or to avoid offering suggestions of industry change that may be occurring. His book may appear a bit dated without this visionary approach.

Major revisions occur in chapters 10, 11, and 15, which deal with futures markets, grades, and marketing costs, respectively. Just as in the first edition, McCoy does a good job of introducing the futures market, its functions, basis, and he provides several hedging examples. Then a new section dealing with research on livestock-hedging strategies is introduced with no orientation to any of the technical or fundamental analysis utilized in selective hedging. This may leave the reader, inexperienced in hedging, somewhat bewildered. With adequate supplementation, an intstructor can lead a class to the importance of McCoy's conclusions. However, it is omissions such as this that may induce the instructor to use McCoy's book as an important reference, but not as the main text of a livestock-marketing class.

The print in the second edition is larger, and the layout is appealing to the intense reader. If you found McCoy's first edition useful, the second edition is a welcome and excellent text. If you are not familiar with the text, and have an interest in livestock marketing, I would recommend you seriously consider the text as a good reference.

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Morgan, Dan. *Merchants of Grain*. New York: Viking Press, 1979, xiv + 385 pp., $14.95.

World trade in grain is dominated by five huge, shadowy, privately held, multinational grain companies controlled by but seven families. This book attempts to document this position by weaving history, the economics and politics of food, political intrigue, economic greed, and personal glimpses into a fascinating book which often times reads more like a mystery and intrigue novel than a chronicle of the real world. Dan Morgan is a journalist for the *Washington Post* who spent three years probing the international grain business and the people that he suggests dominate it. He admits frankly that the story he weaves is a composite of factual knowledge, rumor, and his own perceptions about the current grain-trading system. He was forced to this approach because of the shortage of research material and the general unwillingness of major participants to be interviewed. At some points, Morgan seems almost to be writing an exposé as the final paragraph of his introduction indicates. "I was left with no doubt that the companies at the center of the grain distribution system are not only wealthy but important and very powerful. The time for them to stand up and take a bow is long overdue" (p. xiv). It is possible that some of the families would have preferred their debut to be later and on their own terms. But that aside, the book provides some fascinating glimpses into multibillion dollar business that deals in the world's basic commodity—food.

Morgan is not an economist nor a historian. Thus, the book is not overloaded with deathless

technical jargon nor is it organized in a typical stereotyped way. It reads more like a mystery thriller with seven major and many minor characters who have lifespans of over one hundred years whom the reader must keep track of. The book is the story of five grain companies—Cargill, Continental, Bunge, Louis-Dreyfus and André—which handle, by most peoples' estimates, more than 80% of the world grain trade—and the seven families—Cargill, MacMillan, Fribourg, Borne, Hirsch, Louis-Dreyfus and André—that own them. The book begins with a brief review of the Russian grain purchase of 1975, but immediately reverts to historical sketches of the evolution of the grain trade in the nineteenth century, particularly after the repeal of the Corn Laws in 1845. The first four characters—the Fribourgs, Louis-Dreyfuses, Bunges, and Andrés—are introduced as merchants in the early grain trade. Next, we switch to the evolution of the U.S. grain industry in California and the Midwest and are introduced to Friedlander, Pillsbury, Washburn (General Mills), and Will Cargill. The next three chapters provide a rambling review of developments from 1850 to the present. But lest the reader think the book is a simple chronology, the story darts backward and forward with reckless abandon. Chapters 7 and 8 attempt to define the current dimensions of these multinational giants including substantial doses of family history. Chapter 9 is the closest thing in the book on how a multinational firm actually operates. Chapter 10 presents a set of anecdotes which try to demonstrate the global power of the firms. Chapter 11 deals extensively with U.S. attempts to wield food power against the Soviets in 1975. Chapter 12 is a fascinating treatise on the world rice trade and Tongsun Park. Chapter 13 chronicles the rise and fall of Ned Cook. The last chapter draws the distinction between the commercial grain business and world hunger and concludes that the merchants of grains are concerned only with the former.

Readers will appraise the book differently depending on where they are coming from. Historians might decry the lack of documentation, the dizzying forays back and forth through time, and the personalization of major economic and political events. Economists will be stunned by the absence of hard numbers, formulas, and supply and demand curves. International relations experts might view the geopolitical analysis as overemphasizing food as opposed to bilateral military power and oil. Grain traders would fault some of Morgan's simplifications of the trade. Finally, the grain families no doubt could punch holes in some of Morgan's conjectures should they choose to come out from behind their veils of secrecy. But be that all as it may, the book provides extremely valuable as well as interesting insights into the grain business, even though it is not, nor was it intended to be, a complete description and analysis of the grain trade. One comes away with the sense that the companies' greatest assets are information, superior marketing skills, and entrepreneurial derring-do which often is at variance with widely held social and ethical values.

On first reading, this reviewer was tempted to fault Morgan for not drawing his valuable insights into a tight set of conclusions which portrayed the reality of the grain trade circa 1978. But on rereading the book, this would have destroyed some of its intrigue and readability. Morgan leaves it to the reader to draw his or her own conclusions, though it is quite clear where he stands.

Every serious student of the international grain trade should read this book. It provides more insights into a highly complex, dynamic business than any dozen academic treatises one could select.

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Purcell, Wayne. ***Agricultural Marketing: Systems, Coordination, Cash and Futures Prices.*** **Reston, Va.: Reston Publishing Co., 1979, viii + 472 pp., $15.95.**

This text is intended primarily for the use of the intermediate level undergraduate, with a principal objective "to foster and nuture the problem-solving ability of the marketing student . . . charged with making marketing decisions" (p. 15). In contrast to the theoretical approaches emphasized in most intermediate-level texts, Purcell devotes relatively little time to theoretical models per se, and concentrates instead on the application of theoretical results to contemporary problems. As a result, Purcell's text serves both as a sourcebook of contemporary marketing patterns and as an overview of economic principles relevant to decision making. The descriptive detail, particularly of the livestock industry and of the role of government in price determination and information collection, is not equalled by other texts of this level.

A reduced emphasis on the development of theoretical principles requires expedient application of the implications of economic theory. Unfortunately, the text contains a number of errors and misstatements. For example, quality differentials in cotton grades are presented as evidence of monopolistic competition in production (p. 44); "theory generally supports the position that large size gives market power and market power usually means higher prices and larger profit margins" (p. 73); variables should be retained in models as long as standard errors are less than coefficient estimates (p. 169); hedging in futures markets "often comes at the expense of a significant decrease in the average profit level" (p. 300); spatial equilibrium prices differ by transfer costs only if all countries have identically sloped demand curves and identically sloped supply curves (p. 402).

A second distinctive feature of the book is the emphasis on futures markets. As Purcell points out,

futures markets have been neglected in most texts and nearly one-fourth of the book is devoted to this topic. Unfortunately, Purcell's discussion is devoted largely to chart-reading techniques. Breakouts, congestion areas, head and shoulders, double bottoms, flag formations and other patterns of futures prices are analyzed in great detail. This section provides, at best, a misleading view of futures trading, as there is no theoretical reason or empirical evidence to suggest that successful speculation has been achieved on the basis of a chart-reading strategy. "Buy cheap and sell dear" would have been equally sage advice and would take considerably less space. The important behavioral issues, such as the theory of the cost of storage or the existence of a risk premium, are ignored, and the reader emerges from Purcell's discussion with little understanding of the functions of futures markets.

The emphasis on systems analysis is a third distinctive feature of the book. Purcell considers systems analysis necessary because of the "slow but persistent trend towards vertical integration" (p. 436), the inability of the price mechanism to transmit proper signals to the producer at the end of an increasingly long marketing chain (p. 445), and the potential efficiency gains revealed by a holistic view. Whether systems analysis can contribute substantively to the understanding of market behavior and the role of the price mechanism as a method of inducing change is a controversial topic, and Purcell presents little substantive evidence which might influence the outcome of this argument. The price mechanism for feeder cattle, for example, is asserted to fail because buyers and sellers of feeder cattle have different opinions of ideal animal characteristics, and these differences are not reflected in feeder cattle prices. But the observation that consumers and producers bring different objectives in the market is not surprising. To prove failure of the price mechanism requires a demonstration that consumers place a value on the unpriced characteristics, and Purcell provides no evidence on this issue. The sole example of the ability of a holistic perspective to discover new sources of increased efficiency involves a systems analysis of integrated cattle marketing. Returns on investment for the integrated system increase by less than 2% over decentralized systems (p. 364). Given the large data requirements and the resultant uncertainty of the results of systems analysis, it is difficult to have confidence in such marginal differences.

Purcell's approach is an ambitious one, and the attempts to teach principles through illustrations and relevant examples are admirable. But the distinction between assertion and the implications of theory is critically important to this approach, and Purcell frequently fails to make this difference sufficiently clear. The discussion of futures markets is particularly weak in this regard, and the behavioral aspects of futures markets are almost completely ignored. Finally, little evidence is provided to suggest that systems analysis provides a necessary or useful alternative means of studying the economic principles of marketing behavior.

Eric Monke
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Sinden, John A., and Albert C. Worrell. ***Unpriced Values: Decisions without Market Prices.*** **New York, Toronto: A Wiley-Interscience publication, John Wiley & Sons, 1979, xvi + 511 pp., $25.95.**

The authors, both economists, state that "many people feel it is impossible to place value on [scenic views, California condors, improvements in health, savings in commuting time]. Others feel that they can only be compared by assigning monetary prices to them. We do not agree with either of these views. We believe it is possible to determine comparative values for unpriced things and that valid comparisons can be made without always resorting to monetary prices" (vii). The text is organized in three sections. "Part I considers the nature of values, the kind of value information needed for decisions, the usefulness of comparative values, and the nature and application of basic concepts. Part II gives the reader an appreciation of the large number and wide range of methods that have been developed to measure unpriced values and of how each fills a special niche. Part III considers why decisions involving unpriced values are perceived as difficult and shows how appropriate analyses can overcome this" (viii). Parts I and II are recommended to administrators and policy makers; Parts II and III, to analysts and planners.

These lengthy quotes from the preface are included here to emphasize that the book really is not for the professional economist—or even for students who already have developed an economics perspective. Whether administrators, policy makers, and planners will be likely to pursue the 500-plus pages is another issue, although I will agree with the authors it could do them some good.

The six chapters of Part I basically are devoted to convincing the reader that various unpriced things (goods, experiences, feelings) create utility for people, therefore they have value. While the conventional unit for valuation has been a monetary one, any index that can express benefits in terms comparable with cost, express values of all alternatives in comparable units, or express values for all individuals in comparable units will serve, depending on the specific problem in question. Problems and planning are specific issues, and universal values are not necessary. As with the rest of the book, the arguments are presented lexicographically. Tabular displays and decision trees are abundant. If I had not already believed in the possibility of unpriced values, the authors would have convinced me. However, after 116 pages, I was left with a

nagging feeling of overkill. Only one of the six chapters is specifically on economics as the basis for evaluation—it focuses on elementary concepts of supply, demand, and utility.

In Part II, the next 295 pages, the authors review essentially the whole stock of valuation methods and studies from an applied point of view. Each method and study is classified as to its appropriate problem area and data requirements. Discussion of the pros and cons of alternative methods is pragmatic. There is little discussion of theoretical issues. There are 324 items in the book's list of references—most relate to studies referenced in Part II. Thus, this section takes the form of a meticulous compilation of "abstracts" or of a brief (for each) but lengthy (in total) review of the literature. Topics range from studies using direct questions on value, to discovery of value using signal detection theory. With a few exceptions, the reported studies were published previous to 1976. Part II could be used as a thesaurus of evaluation methods, but for continuous reading it is the least successful part of the book.

In Part III the authors return to the argument for making unpriced evaluations, and give several detailed examples of how such evaluations have been made in reputedly difficult cases. It is a cogent summary of when to use a monetary, utility, or mixed approach to evaluation for decision making.

The final sentence, however, is the best statement in the whole book: "The model of value in Equation 3.5 provides a basis for valuing unpriced benefits and costs of any kind and under any circumstances" (p. 490). Equation 3.5 is

$$Vi = Ui - DUi,$$

where Vi is the value of thing i, Ui is its utility, and DUi is the disutility involved in obtaining it. That equation was given 333 pages previously. From this reviewer's point of view, the space between the equation and the final statement could have been a good deal shorter.

I am left with mixed feelings about this meticulously crafted effort. The work put into it is appreciated, but I am afraid most people will not have the strength of character to sort through the mass of information to obtain the particular technique the authors specify as "right" for their problems. Having done so, they would still need to investigate the specific literature in detail. Thus the book offers little to an evaluator who is familiar with the literature. An administrator or policy maker is likely to be put off by the sheer volume of material. As a text for student analysts, it would serve as an outline to be supplemented with the analyses themselves.

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Thiam Tan Bock, and Ong, Shao-er. *Readings in Asian Farm Management*. Singapore: Singapore University Press, 1979, x + 350 pp., $15.00.

The book is the culmination of the efforts of a group of farm management teachers in Asian universities who met under the auspices of the Agricultural Development Council, New York, and felt the need of a book on farm management in the Asian context. Thus, this book is not a comprehensive treatment of the subject matter of farm management, but rather a collection of articles selected by a committee consisting of experienced teachers in Asian universities.

In all, twenty-four articles have been selected from respectable journals, articles considered relevant for farm management courses in Asian universities. The articles present farm management problems and data from most of the Asian countries and successfully present an Asian, rather than an individual country, outlook. The articles are grouped in five parts which would represent a major topic in any course on farm management. The four articles in Part I deal with economic principles and applications. The principal tools of farm management, such as production function analysis and linear programming, have been presented with practical examples from the Asian agricultural economy. All articles selected are technical, empirical, and useful for the course.

Part II deals with farm business and management analysis. Here there are also four papers touching on problems of data collection, data analysis, decision making in the adoption of new high-yielding varieties of rice and optimum combination of farm resources in livestock production, and so on. Though all four articles are technical and empirical, yet one feels the lack of an article dealing with total farm business analysis of small farms combining both crop and animal husbandry enterprises. This would have increased the awareness of both teachers and students on the decision making process on small farms. The article by V. H. Park on behavior of farm resources in livestock production on semi-subsistence farms does not fulfil this need.

Part III deals with institutional factors affecting management. The four articles in this section discuss credit, cooperation, joint farming, and crop insurance. Whereas the authors have comprehensively dealt with the various aspects of these topics, one wonders why an article on land tenure, the biggest institutional factor in agricultural development in Asia, has not been included.

Part IV includes six well-chosen articles on the "Economics of Technological Innovations." The articles deal with the most important technological changes in recent years, such as farm mechanization, implication of green revolution, responsiveness of subsistence farmers to new ideas, rice-harvesting techniques, and demonstrate how technological changes modify farm management decisions. The articles should increase the teachers' and students' understanding of farm management problems vis-à-vis technological innovations.

Part IV includes six well-chosen articles on the and implications, and deals with such topics as allocation efficiency in a developing agricultural econ-

omy, impact of high-yielding varieties of rice on economic aspects of animal husbandry, farm income distribution, and choice of techniques in rice milling. These articles highlight the use of farm management studies on policy formulation and its impact on farmers income. Here, again, one feels a lacunae, the need of an article on price policy, so vital an issue to farm policy in Asia.

Since farm management is a compulsory course in all undergraduate programs in agriculture and agricultural economics in Asia, and because there is a woeful lack of textbooks with Asian data, this book fulfills a great need. The articles have been well selected and integration of economic theory with farm management problems has been achieved in the book to a considerable extent. The book should prove useful both to teachers and to students of the subject in Asia.

S. L. Shah
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Articles

Wheat Cartelization and Domestic Markets

Robert G. Chambers and Michael W. Woolverton

The effects of cartelization in the international wheat market are analyzed. Particular attention is given to the relationship between the level of cartel profits and the price farmers receive for their wheat. Sufficient conditions are established for a rise in cartel profits to be associated with a rise in the farmgate price of wheat. The potential stability of a cartel formed by the major trading companies also is investigated and a means of preventing cheating is introduced and discussed.

Key words: cartels, cartel price, farmgate price.

In the last decade there has been a series of startling events in the international grain arena which has evoked an increasing amount of attention on the part of agricultural economists. An important topic of discussion in the resulting flurry of theoretical and empirical literature has been the competitive structure of the international wheat and other grains markets. McCalla (1966) appears to have been the first entrant into the fray with his pathbreaking duopoly model of the world wheat market. Subsequent work includes a triopoly model of the world wheat market (Alaouze, Watson, Sturgess) and another important contribution by McCalla (1977) outlining an array of strategies that market participants might attempt to follow and the resulting market situations that could arise from their actions. Most recently, Carter and Schmitz have presented empirical evidence which they feel suggests that the major wheat importers are charging approximately an optimal tariff.

The idea of forming an international wheat-trading cartel made up of major exporting firms and national trading entities has received widespread attention both in and out of the economics profession. Many students of international trade reject such a cartel as impractical, but the idea persists. For instance, the popular slogan "food for crude" and the attention given to this issue by the popular media suggest that there is some popular sentiment (in the United States at least) for exercising potential monopoly power in world grain markets. Such sentiment, if sufficiently backed by popular pressure on legislators, could lead to a significant easing of current anticartel laws, which would allow exporters a chance to reap some of these potential monopoly profits. Even without changes in antitrust legislation, multinational firms and state exporters may form such a trading agreement sub-rosa. And yet, the question remains: will formation of a cartel benefit individual farmers as well as members of the cartel? We hope to illuminate this problem in the succeeding pages.

Relatively little attention has been given to the formation of optimal strategies for some of the major participants on the supply side of the international grain trade—the large grain companies such as Cargill, Continental, Bunge—and the effect such practices could have on farmers in the exporting nations. At first glance, the optimal strategy is rather apparent; i.e., these large sellers should exploit any monopoly-monopsony power they possess. This, however, does not take into account the fact that most of the operations of these firms are located in the United States and other major exporting regions. Hence, one must recognize that the exporting regions, for political and other reasons, may not allow these firms a free hand. Specifically, it is assumed in the ensuing analysis that the exporters are not allowed systematically to extract economic surplus from the domestic suppliers; i.e., they

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are forced to act in a relatively competitive manner in buying the grain.

The present paper investigates in a general framework the optimizing behavior of a cartel formed by, say, the dominant grain export firms or even by these firms and the marketing boards of large exporting nations (Canada, Australia). Because an important argument for the formation of a cartel is that it allows exporting nations to capture some otherwise unrealizable monopoly profits, an examination of the effect on the ultimate suppliers of the wheat (i.e., farmers) is vital to any discussion of cartel behavior. Hence, it will be argued that formation of a cartel might in fact lead to a lower farm level price for wheat, even if the cartel acts competitively in buying the grain domestically. The link between the level of cartel profits, the farmgate price of wheat and the cartel price, also is examined by using comparative static analysis to investigate the effects of changes in the international demand situation. Under certain assumptions, it is possible to demonstrate that higher cartel profits will be linked with a higher farmgate price and a lower cartel price. In general, however, it is demonstrated that there is no a priori reason to expect that the price farmers receive for their grain will vary positively with the level of cartel profits. The last section of the paper is devoted to examining the stability of such a cartel. Because it is demonstrated easily that each member of the cartel will have an incentive to cheat, the problem of deterring cheating is crucial to any discussion of cartel stability. Accordingly, Osborne's quota rule, which is designed to prevent cheating, is introduced, and its implications for the cartel under discussion are examined.

The Model

Consider an industry with m firms, each of which buys grain in the domestic market and then markets it internationally. Assume that the firms act together so as to maximize joint overall profits.[1] It is assumed that each member of the cartel is forced to act as a price taker in buying grain and any other inputs to the marketing process. Also, suppose there exists a given, convex technology for taking unprocessed grain from the farm level, processing it, and bringing it to the market place, that can be represented by the functional relationship,

$$Q = \sum_{i=1}^{m} Q_i = F(\mathbf{x}),$$

where Q is grain as marketed; $\mathbf{x}$ is a vector of inputs to this processing function including unprocessed grain, storage, transportation, and such capital equipment as dryers and aerators; and F is a twice continuously differentiable, concave, and increasing function of its arguments. Following Diewert (pp. 74–75), the monopoly power of the cartel will be represented by the price relationship $p = wD(Q)$, where p is the price of the grain sold by the cartel, D is assumed to be differentiable, and $w > 0$ represents a shift parameter reflecting demand conditions in the market.[2]

The solution to the cartel's profit-maximization problem defines the profit function,

$$(1)\quad \pi^*(w,\mathbf{v}) = \underset{p,Q,\mathbf{x}}{\text{Max}}\ (pQ - \mathbf{v}'\mathbf{x}),$$
$$= \underset{\mathbf{x}}{\text{Max}}\ \{wD[F(\mathbf{x})]\ F(\mathbf{x}) - v'\mathbf{x}\},$$

where $\mathbf{v}$ is a column vector of input prices. Hotelling's lemma, or a direct application of the envelope theorem, yields

$$(1a)\quad \Pi^*_w \equiv \frac{\partial \pi^*(w,\mathbf{v})}{\partial w} = DQ = \frac{pQ}{w} \equiv R(w,\mathbf{v}),$$

$$(1b)\quad \Pi^*_i \equiv \frac{\partial \pi^*(w,\mathbf{v})}{\partial \mathbf{v}_i} = -\mathbf{x}_i(w,\mathbf{v}),$$

$$(1c)\quad \pi^*(\lambda w,\lambda \mathbf{v}) = \lambda \pi^*(w,\mathbf{v}) : \lambda, w, \mathbf{v} > 0.$$

[1] If the cartel is composed only of large firms, it is probably accurate to suppose that profit maximization of the cartel would be their joint goal. On the other hand, if some of the large government marketing boards are involved in the cartel, then, following Bieri and Schmitz, it may well be inaccurate to presume short-run profit maximization since a marketing board may find it advantageous to manufacture price stability by manipulation of its stockholding policy. Their model, however, assumes that the cartel is concerned with the level of return to producers. Such is not necessarily the case if the major export firms are involved in the cartel.

[2] For example, w could be disposable personal income or even a linear homogenous function of other factors affecting international demand (see Diewert). Hence, this specification allows sufficient flexibility for the existence of competitors in the international market. Note that the more usual inverse demand formulation, $p = D(Q)$, is a special case of the above specification where $w = 1$. Thus, any conclusions drawn here extend directly to this more familiar case. For heuristic purposes the reader might conceptualize $D[F(\mathbf{x})]F(\mathbf{x})$ as a pseudo-production function as suggested by Diewert; w would then be the "price" associated with this pseudo-production function and the resulting profit function would be a function of input prices and the "price" of the pseudo-output.

This specification also implicitly assumes that the cartel is allowed to exercise its monopoly power over the consumers in the home countries of the cartel. Obviously this is somewhat unrealistic but considerably sharpens the results. Alternatively one could rely on a heroic assumption often used in trade analysis, i.e., there is no domestic consumption of the commodity in question by the exporting regions, to justify this specification.

That is, partial differentiation of the profit function with respect to w yields revenue deflated by w or the deflated revenue function; differentiation with respect to the ith factor price obtains minus the profit-maximizing demand $[\mathbf{x}_i(w,\mathbf{v})]$ for the ith input; and the profit function is linear homogenous in w and $\mathbf{v}$. Letting

$$\Pi^*_{iw} = \frac{\partial^2 \pi^*(w,\mathbf{v})}{\partial \mathbf{v}_i \partial w},$$

it follows that $\Pi^*_{iw} = \Pi^*_{wi}$. A direct consequence of this fact, the concavity of $F(\mathbf{x})$ and $(a - c)$, is that the matrix defined by

$$\text{(2)} \quad \begin{bmatrix} \Pi^*_{11} & \Pi^*_{12} & \cdots & \Pi^*_{1n} & \Pi^*_{1w} \\ \Pi^*_{21} & \Pi^*_{22} & \cdots & \Pi^*_{2n} & \Pi^*_{2w} \\ \cdot & & & & \\ \cdot & & & & \\ \Pi^*_{n1} & \Pi^*_{n2} & & \Pi^*_{nn} & \Pi^*_{nw} \\ \Pi^*_{w1} & \Pi^*_{w2} & & \Pi^*_{wn} & \Pi^*_{ww} \end{bmatrix} \equiv \nabla^2 \Pi^*$$

is positive semidefinite and symmetric; and further, that (see Diewert, p. 75)

$$\text{(2')} \quad \nabla^2 \Pi^* \begin{bmatrix} \mathbf{v} \\ w \end{bmatrix} = \mathbf{0}_{n+1},$$

where $\mathbf{0}$ represents a vector containing only zeroes. Put another way, the fact that the profit function is linear homogenous in factor prices and $w(c)$ coupled with its derivative property (a and b) implies, by a basic property of homogenous functions, that the derived factor demands of the cartel are homogenous of degree zero in factor prices and w, which in turn implies that $\nabla^2 \Pi^*$ is singular.

Because a cartel operates on the basic principle of increasing profits by effectively rationing the amount of processed grain it sells, one might expect that cartel sales are lower than sales associated with free trade. Obviously, this need not always be true since there may be certain demand and supply conditions under which the volume of sales would coincide. Furthermore, in a dynamic framework with the possibility of stockholding, there could exist cases where the cartel might actually sell more than under competitive conditions. At any one point in time, however, it does not seem unreasonable to assume that cartel sales usually will be lower than those under competition. If this is the case, and the possibility of storing processed grain is abstracted from, the formation of a cartel should lead to a lower processing rate than under free trade. Heuristically, a lower processing rate is associated with a lower factor utilization rate and hence a lower derived factor demand. This should be especially true of the main ingredient to the process $F(\mathbf{x})$—unprocessed wheat. At an intuitive level, one thus expects that the demand for unprocessed wheat under a cartel is less than under a competitive system. It is important to recognize that this does not follow from an attempt by the cartel to extract monopsonistic profits from suppliers of raw materials, rather it is a direct result of the fact that monopoly profits generally accrue as a result of restricting the level of sales and an effective auctioning policy. Although the equilibrium price for wheat at the farm level in the final analysis will be the result of demand and supply interaction, it might be expected that under certain realistic conditions the farmgate price (and farm revenues) will be lower under a cartel than under competition because it is likely that the demand for unprocessed wheat under a cartel will be less than under competitive conditions. Therefore, it appears that farmers may have no incentive to participate in this type of cartel unless there is some effective means to obtain a portion of the monopoly profits that accrue to the cartel. One means that does not affect cartel sales is to tax profits of the cartel at a constant rate and redistribute the proceeds to farmers. That is, if the government decides to tax away $(t \times 100)\%$ of the cartel profits, the cartel's profit maximization problem becomes

$$\underset{\mathbf{x}}{\text{Max}}\ t^*\{wD[F(\mathbf{x})]\ F(\mathbf{x}) - v'\mathbf{x}\},$$

where $t^* = (1 - t)$. Of course, the solution to this problem in terms of the utilization of $\mathbf{x}$ is the same as for the original cartel problem. Hence, pretax cartel profits and factor utilization are the same as in the original problem. However, the taxing authority now has $t\pi^*(w,\mathbf{v})$, which can be redistributed among the various factors.

The interested reader should note that this result actually is a much weaker result than that reported in a recent paper by Carter, Gallini, and Schmitz. Their paper shows that producers conceivably could be worse off under a government-operated export cartel—i.e., one which actually takes producer surplus at the farm level into account—than under free trade. Furthermore, Carter, Gallini, and Schmitz present some empirical evidence to suggest that under present demand and supply conditions this would be the case if such a government-operated cartel is formed.

The Linkage between Cartel Profits, Factor Payments, and Cartel Prices

These assumptions and results can be used to investigate further the relationship between conditions in the international market (as represented by w) and the domestic market for the factors of production. First, note that by (1*a*) and (1*b*) above, an increase in w (caused by, say, a shortfall in world production such as a failure of the Soviet crop) or a decrease in any factor price will increase cartel profits.

Before proceeding to the general analysis, however, it is convenient to state as a lemma a partial version of a theorem due to Takayama. This result plays an important role in the ensuing analysis of the linkage between cartel profits, factor payments, and cartel prices.

LEMMA: *Let B be an $n \times n$ matrix whose off-diagonal elements are all nonnegative. Then the following conditions are mutually equivalent:*

(*a*) *There exists a vector* $\mathbf{x} \geq 30$ such that $B\mathbf{x} < 0$.

Proof: See theorem 4.*D*.3 of Takayama (p. 393).

This result is particularly important because of the singularity of $\nabla^2\Pi^*$. In carrying out the comparative static analysis of the model, it is essential to have conditions which insure consistent invertibility of the fundamental comparative static equation.

Using (*b*), simultaneous equilibrium in the factor markets is representable as

$$(3) \quad -\Pi^*_i\,(w,\mathbf{v}) = S_i\,(\mathbf{v}_i) = Q_i \qquad i = 1, 2, \ldots, n,$$

where $S_i\,(\mathbf{v}_i)$ is the domestic supply situation and Q_i is the equilibrium quantity exchanged. Note that all sources of demand for the factors of production other than the cartel are abstracted from in the following. Hence, the comparative static effect of a change in w on factor prices in matrix form is

$$(4) \quad \begin{bmatrix} (-\Pi^*_{11} - S_{11}) & -\Pi^*_{12} & -\Pi^*_{1n} \\ -\Pi^*_{21} & (-\Pi^*_{22} - S_{22}) & -\Pi^*_{2n} \\ \vdots & & \\ -\Pi^*_{n1} & -\Pi^*_{n2} & (-\Pi^*_{nn} - S_{nn}) \end{bmatrix} \begin{bmatrix} dv_1 \\ dv_2 \\ \\ dv_n \end{bmatrix} = \begin{bmatrix} \Pi^*_{1w} \\ \Pi^*_{2w} \\ \\ \Pi^*_{nw} \end{bmatrix} dw,$$

where $S_{ii} = \dfrac{\partial S_i}{\partial v_i}$. Converting to elasticity form obtains

$$(4') \quad \begin{bmatrix} (\epsilon_{11} - \Theta_{11}) & \epsilon_{12} & \epsilon_{1n} \\ \epsilon_{21} & (\epsilon_{22} - \Theta_{22}) & \epsilon_{2n} \\ \vdots & & \\ \epsilon_{n1} & \epsilon_{n2} & (\epsilon_{nn} - \Theta_{nn}) \end{bmatrix} \begin{bmatrix} \hat{\mathbf{v}}_1 \\ \hat{\mathbf{v}}_2 \\ \\ \hat{\mathbf{v}}_n \end{bmatrix} = - \begin{bmatrix} \epsilon_{1w} \\ \epsilon_{2w} \\ \\ \epsilon_{nw} \end{bmatrix} \hat{w},$$

where $\epsilon_{ij} = \dfrac{\partial \mathbf{x}_i}{\partial \mathbf{v}_j} \dfrac{\mathbf{v}_j}{Q_i} = \dfrac{-\Pi^*_{ij}}{Q_i}\,\mathbf{v}_j$, $\Theta_{ii} = \dfrac{\partial S_i}{\partial \mathbf{v}_i} \dfrac{\mathbf{v}_i}{Q_i}$, $\epsilon_{iw} = \dfrac{\partial \mathbf{x}_i}{\partial w} \dfrac{w}{Q_i} = \dfrac{-\Pi^*_{iw}}{Q_i}\,w$, and carets denote percentage change. Without loss of generality, let us examine $\hat{\mathbf{v}}_1$. Cramer's rule implies

$$(5) \quad \frac{\hat{\mathbf{v}}_1}{\hat{w}} =$$

$$\frac{\begin{vmatrix} -\epsilon_{1w} & \epsilon_{12} & \epsilon_{1n} \\ -\epsilon_{2w} & (\epsilon_{22} - \Theta_{22}) & \epsilon_{2n} \\ \vdots & & \\ -\epsilon_{nw} & \epsilon_{n2} & (\epsilon_{nn} - \Theta_{nn}) \end{vmatrix}}{\begin{vmatrix} (\epsilon_{11} - \Theta_{11}) & \epsilon_{12} & \epsilon_{1n} \\ \epsilon_{21} & (\epsilon_{22} - \Theta_{22}) & \epsilon_{2n} \\ \vdots & & \\ \epsilon_{n1} & & (\epsilon_{nn} - \Theta_{nn}) \end{vmatrix}} = \frac{\begin{vmatrix} -\epsilon_{1w} & \epsilon_{12} & \epsilon_{1n} \\ -\epsilon_{2w} & (\epsilon_{22} - \Theta_{22}) & \epsilon_{2n} \\ \vdots & & \\ -\epsilon_{nw} & \epsilon_{n2} & (\epsilon_{nn} - \Theta_{nn}) \end{vmatrix}}{\begin{vmatrix} (-\epsilon_{1w} - \Theta_{11}) & \epsilon_{12} & \epsilon_{1n} \\ (-\epsilon_{2w} - \Theta_{22}) & (\epsilon_{22} - \Theta_{22}) & \epsilon_{2n} \\ \vdots & & \\ (-\epsilon_{nw} - \Theta_{nn}) & & (\epsilon_{nn} - \Theta_{nn}) \end{vmatrix}}$$

The second equality follows from (2′), which implies that $\sum_{j=1}^{n} \epsilon_{ij} = -\epsilon_{iw}$ and the fact that adding columns of a matrix does not change its determinant (e.g., theorems 1.5.2 and 1.5.7 of Graybill). General statements about the sign of (5) do not seem available; however, some important special cases do exist. For example, suppose that the supply of each factor is perfectly inelastic ($\Theta_{ii} = 0$); the immediate conclusion from (5) is that $\frac{\hat{v}_1}{\hat{w}} = 1$. If factor supply is perfectly inelastic a strengthening in international demand reflected by an increase in w leads to an equal percentage increase in the level of all factor prices. Also recall that by (2′),

$$(6)\quad \begin{bmatrix} -\Pi^*_{11} & -\Pi^*_{12} & \cdots & -\Pi^*_{1n} \\ -\Pi^*_{21} & -\Pi^*_{22} & \cdots & -\Pi^*_{2n} \\ \vdots & & & \\ -\Pi^*_{n1} & -\Pi^*_{n2} & \cdots & -\Pi^*_{nn} \end{bmatrix} \begin{bmatrix} v_1 \\ v_2 \\ \vdots \\ v_n \end{bmatrix}$$

will be negative (positive) if the vector $\Delta' = [\Pi^*_{1w} \text{----} {}^*_{nw}]$ is negative (positive). Given that all $S_{ii} > 0$, this implies

$$(6')\quad \begin{bmatrix} (-\Pi^*_{11} - S_{11}) & -\Pi^*_{12} & & -\Pi^*_{1n} \\ -\Pi^*_{21} & -\Pi^*_{22} - S_{22} & & -\Pi^*_{2n} \\ \vdots & & & \\ -\Pi^*_{n1} & -\Pi^*_{n2} & & (-\Pi^*_{nn} - S_{nn}) \end{bmatrix} \begin{bmatrix} v_1 \\ v_2 \\ \vdots \\ v_n \end{bmatrix}$$

will be negative if Δ is negative. If it is further assumed that all of the off-diagonal elements of the matrix on the left-hand side of (4) are nonnegative, i.e., all factors of production are substitutes (in the sense that $\Pi_{ij} < 0$), then the above lemma implies that the solution vector $dv = [dv_1, \ldots, dv_n]'$ associated with (4) will be positive. Thus, in the case where $\Delta < 0$ and all factors are substitutes an increase in w leads to an increase in all factor prices. In two special cases, therefore, it is possible to unambiguously sign the vector dv.

Consider, however, what it means for Δ to be negative. Recall that $\Pi_{iw} = \Pi_{wi} = \frac{\partial R}{\partial v_i}$. Thus, for each element of Δ to be negative, it is necessary that the marginal effect on cartel revenues (deflated by the shifter w) of a change in each factor price be negative. In other words, an increase in any factor price, *ceteris paribus,* must lead to a fall in adjusted revenues. Further, it follows from (2′) and the symmetry of $\nabla^2\Pi^*$ that

$$(7)\quad \frac{\partial R}{\partial v_i} = \frac{\sum_{j=1}^{n} v_j \frac{\partial x_i}{\partial v_j}}{w}.$$

Hence, a sufficient condition for (7) to be negative is that all factors be complements (in the sense that $\Pi_{ij} > 0$). Yet, to invert the relationship in (4) and obtain a unique sign for dv, it was assumed that all goods are substitutes. Multiplying both sides of (7) by $\frac{1}{x_i} > 0$ and rewriting in elasticity form yields

$$(7')\quad \frac{\partial R}{\partial v_i} \frac{1}{x_i} = \frac{\sum_{j=1}^{n} \epsilon_{ij}}{w}.$$

So, given a world of substitutes and that

$$\frac{\partial x_i}{\partial v_i} < 0,$$

a necessary condition for $\frac{\partial R}{\partial v_i}$ to be negative is that $|\epsilon_{ii}| > \left| \sum_{j \neq i}^{n} \epsilon_{ij} \right|$, i.e., the sum of the cross-price elasticities be less than the own-price elasticity in the absolute value. These results establish:

PROPOSITION A: *Given the model specified above, all factor prices will be unit elastic with respect to* w *if factor supply is completely inelastic for all factors.*

PROPOSITION B: *In a world of substitutes, if each $S_{ii} > 0$ and for all factors the absolute value of the own-price elasticity exceeds the absolute value of the sum of the cross-price elasticities all factor prices will rise if* w *rises.*

Before we proceed further, it is worthwhile to examine just what type of behavior one would expect from such a cartel is substitutability is assumed. Substitutability implies that if the price of the ith input rises, then demand for all other inputs will rise as the cartel substitutes out of the now relatively more expensive input. This may seem quite intuitive, but it ignores the peculiar character of the cartel under discussion. Among the inputs to the processing function $[F(\mathbf{x})]$, a key ingredient is

unprocessed wheat. If the price of unprocessed wheat rises, one should not expect the cartel to substitute all other inputs. Rather, one expects unprocessed wheat to be a complement with at least some of the other inputs into the F process.[3]

The preceding arguments demonstrate some sufficient conditions for the solution (**dv**) to (4) to assume an unambiguous sign. However, the very restrictive nature of the assumptions, zero elasticity in the one case and everywhere substitutability in the other, suggests that it is unlikely that **dv** in (4) will ever assume, a priori, a unique sign. If this is so, then in general one cannot a priori prèsume that any element of **dv** will be positive. Hence, we have not been able to establish that an increase in w which does lead to higher cartel profits will also lead to higher farmgate prices for wheat. By the same token, precious little information is available for determining the effect on other input prices of an increase in w. Cartelizing, therefore, may not insure that farmers or the owners of these factors will reap higher returns for their wheat if the cartel attempts to maximize joint profits.

Turning to the effect on cartel price of an increase in w and thus, to some extent, to the linkage between the cartel price and the price of wheat to farmer,[4] differentiate the optimal cartel price $p^* = wD[F(\mathbf{x}^*)]$, where $\mathbf{x}^* = [-\Pi^*_1, \ldots, -\Pi^*_n]'$ with respect to w to obtain

$$(8)\quad \frac{\partial p^*}{\partial w} = D + w\frac{\partial D}{\partial F}\left[\sum_{j=1}^{n}\frac{\partial F}{\partial \mathbf{x}^*_j}\frac{\partial \mathbf{x}^*_j}{\partial w}\right] = D - w\frac{\partial D}{\partial F}\left[\sum_{j=1}^{n}\frac{\partial F}{\partial \mathbf{x}^*_j}\frac{\partial R}{\partial \mathbf{v}_j}\right].$$

The second equality follows from the symmetry of $\nabla^2\Pi^*$, which implies that $\frac{\partial \mathbf{x}^*_i}{\partial w} = -\frac{\partial R}{\partial \mathbf{v}_i}$. If it is assumed that $\frac{\partial R}{\partial v_j} < 0$ for all j, then the sign of (8) is a priori indeterminate. This forces the conclusion that one cannot always establish a unique relationship between the price farmers receive for their wheat and the cartel price because, as demonstrated above, a sufficient condition for the farmgate price to increase is that all $\frac{\partial R}{\partial \mathbf{v}_j} < 0$. For example, suppose that all factors are indeed substitutes and, further, that the own-price elasticity dominates the cross-price elasticities in all cases. As demonstrated above, this assures that **dv** in (4) will be unambiguously positive, i.e., an increase in w will lead to higher returns for each factor. Now return to (8). Since the price the cartel will charge, *ceteris paribus*, is a decreasing function of its sales and marginal product is always positive, then the second term after the second equality necessarily will be negative when $\frac{\partial R}{\partial \mathbf{v}_j} < 0$, for all j. The first term, however, is positive and a priori there is no way to determine whether the absolute value of the first term dominates that of the second or vice-versa. If the second (first) dominates the first (second), then (8) is negative (positive).

To recapitulate, it has been established that an increase in w, reflecting, say, a shortfall in world production, leads to higher cartel profits and possibly higher farm level and cartel prices. In fact, if one retreats to a one input model (with a downward sloping factor demand curve) one can unambiguously conclude that the farm level wheat price would rise. This, however, is not the general result, and it remains a possibility that an increase in w actually could lead to a lower price for wheat at the farm level. Intuitively, one might suspect that the price of wheat at the farm level will rise while, say, the price of storage would fall as less storage is demanded, but the possibility of a paradox still remains. One policy recommendation is to insure that increased demand does lead to higher returns for wheat farmers by levying a proportional tax on the cartel and distributing the tax revenues among the factors.

Cartel Stability

One of the most important problems facing any cartel is the problem of cartel stability since a cartel has to survive to be of any long-run consequence. Some of the major barriers to stability are external competition, sharing of cartel revenues, locating the contract surface, and detecting and deterring cheating by members. To some extent we have already investigated via w the response of the cartel to external competition.

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[3] Of course, more care, that is, more usage of other factors, will allow the processor to extract more processed wheat from a given amount of unprocessed wheat and there is a possibility for some local substitution. However, this effect is limited and there is definitely a point beyond which unprocessed wheat cannot be substituted for.

[4] We would like to thank an anonymous reviewer for suggesting this area of research.

Cheating, however, is perhaps the most important problem any cartel faces. For a cartel to be effective, it is necessary that all firms cooperate and not exceed the optimal level of sales, or cartel profits will fall. Extensive, sustained cheating will almost certainly break a cartel because cheating by one or more members leads to lower profits for all other members of the cartel; thus, there is little incentive for these members to cooperate in cartel arrangements. However, all firms participating in this type of cartel have the incentive to cheat. This is a well-known result which is easily explained. Suppose that the cost function of the ith cartel member can be represented as $C_i(Q_i)$. Profit maximization for the cartel requires

$$(9) \qquad w\left[D + Q\frac{\partial D}{\partial Q}\right] = \frac{\partial C_i}{\partial Q_i}.$$

Now, if each firm were to maximize its own profits (assuming that the pricing structure does not change), it would act in such a manner that

$$(10) \qquad w\left[D + Q_i\frac{\partial D}{\partial Q}\right] = \frac{\partial C_i}{\partial Q_i}.$$

Hence, profit maximization for the cartel requires each firm to equate its marginal cost to the marginal revenue of the cartel as whole; whereas, in maximizing its own profits, the firm equates its marginal cost to its marginal revenue. Evaluating (9) and (10) at the optimal cartel output Q^* obtains

$$(11) \qquad \frac{\partial C_i(Q^*_i)}{\partial Q_i} = w\left[D + Q^*\frac{\partial D(Q^*)}{\partial Q}\right] \leq w\left[D + Q^*_i\frac{\partial D(Q^*)}{\partial Q}\right],$$

since $Q^*_i \leq Q^*$ by definition. Thus, each firm's marginal revenue is greater than or equal to its marginal cost at the cartel point. Consequently, each firm has an incentive to expand its output. However, an expansion of output by even one firm would lead to a fall in cartel profits. This problem can be represented graphically using the isoprofit contours for each firm. The contract curve of possible cartel solutions is the locus of tangencies between the isoprofit curves of the n firms (e.g., $\Pi_j{}^i$), i.e., points which are Pareto optimal in the sense that movement away from them signals a decline in profits for at least one member of the cartel. Therefore, in the two-firm case we can represent the contract curve as DD in figure 1, where superscripts represent decreasing levels of profit and subscripts represent firms (e.g., $\Pi_1{}^2 > \Pi_1{}^1$).

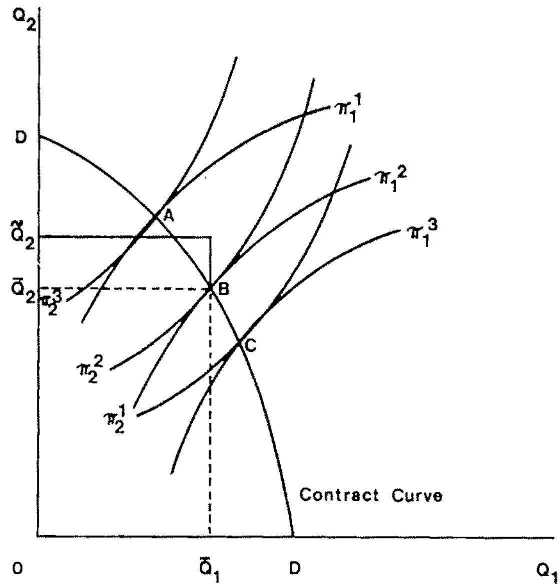

Figure 1. The optimal cartel solution

Once the cartel locates the contract curve and chooses a cartel point, say B, suppose the second member of the cartel decides to cheat by increasing exports from the cartel amount $\bar{Q}_2$ to $\tilde{Q}_2$ in figure 1. While this increases profits above profit level $\Pi_2{}^2$, the profits of the other cartel member falls below $\Pi_1{}^2$, which in turn is an incentive for the loyal member to diverge from the cartel solution. In game-theoretic terms, the cartel faces a prisoner's dilemma, where as a whole the cartel is better off if no one cheats but each individual has an incentive to cheat.

However, it is easy to demonstrate that the objective function of the above cartel will allow the application of the quota rule established and discussed in Osborne (1976, 1978) and Holahan to deter cheating. We define

$$S_i = \frac{\bar{Q}_i}{\sum_{j=1}^{n} \bar{Q}_j}$$

as the ith firm's market share at the cartel point $[\bar{Q} = (\bar{Q}_1, \bar{Q}_2, \ldots, \bar{Q}_n)']$. Osborne's quota rule for the ith member of the cartel is to process and sell

$$\text{Max}\left[\bar{Q}_i, \bar{Q}_i + S_i \frac{\sum_{k\epsilon K}\Delta Q_k}{\sum_{k\epsilon K} S_k}\right],$$

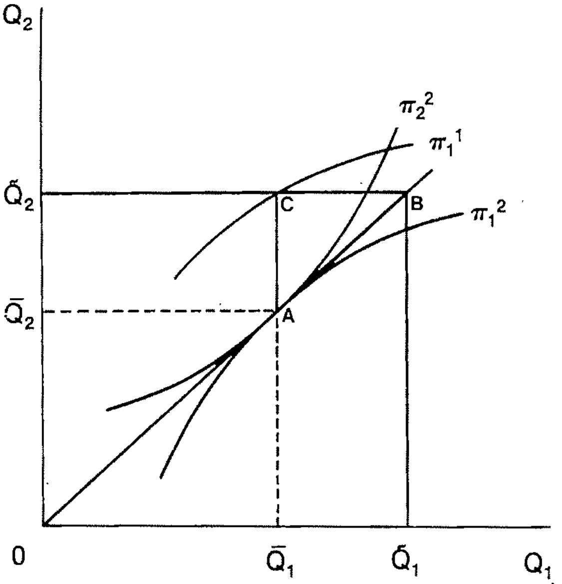

Figure 2. The ray property and cheating

where ΔQ_k is the amount by which the kth member of the cartel cheats and K represents the group of cheaters. In other words, to prevent cheating, each firm maintains a constant market share. In the case of a two-member cartel, this decision rule is demonstrated in figure 2. Let A represent the cartel point. If the second member decides to cheat by exporting $\tilde{Q}_2$ instead of $\bar{Q}_2$, the first firm's response under the quota rule would be to sell $\tilde{Q}_1$, which is the amount necessary to maintain the same share as at the cartel point. If firm 2 expects firm 1 to react in this fashion it will not usually cheat because at B, its profit is lower than at A. Furthermore, in most cases firm 1 will have the incentive to move to B, because it loses less profit than if it remained at C without retaliating. Osborne demonstrates that maintaining market share is effective in preventing cheating only if the hyperplanes tangent to each member's isoprofit surface intersect in a line which is ray from the origin.[5] If the cartel point satisfies this condition, it is said to have the "ray property." Holahan demonstrates that cartels of the type discussed above have the critical "ray property" that makes Osborne's quota rule an effective method of deterring cheating in many instances.

Given that there appears to be a feasible deterrence program that the cartel could enact to limit cheating, we turn to the problem of discovering cheating. Deterrence is only effective if cheating is discovered. For the case of the international wheat market, it could be argued that there would be a time lag between cheating and discovery. All of the major grain companies maintain highly sophisticated information networks, as do the governments of the major exporters, with various methods including inspection programs. Hence, although there may be a time lag involved in the discovery process, it should be relatively short and probably could be compensated for by following Osborne's suggestion and adjusting the quota rule so as to keep the expected vector of sales on the ray from the origin.

The final problem facing the cartel, therefore, is the sharing of cartel revenue. Basically stated, a firm will not participate in the cartel if it can expect to achieve a higher return by acting outside the cartel or by buying out the other members of the cartel and acting as a pure monopolist.[6] The latter point may not be particularly relevant for members of an international cartel that may include some government-owned corporations (such as the Canadian Wheat Board), but it should be considered for completeness' sake. That the firms can earn more in a cartel that rigorously enforces the market share rule suggested by Osborne is obvious from previous discussion. Osborne (1976, pp. 840–1) demonstrates that any solution to the cartel problem which has the "ray property" also insures that a member can be no better off by buying out the other cartel members. Therefore, maintenance of market share will provide a feasible means for sharing the cartel revenues while it simultaneously deters cheating. In this respect, the solution to the sharing problem is very similar to that detailed for a triopoly model suggested in Alaouze, Watson, and Sturgess.

Concluding Remarks

Much discussion in the popular press has centered on the feasibility of major grain ex-

[5] Holahan has noted that in the case of extremely antisymmetrical cost structures it may not pay firm 1 to move to a point on the ray from the origin. However, we agree with Osborne's (1978) reply that this seems to be fairly unimportant in practice. The reader will also note that there have been other proposals that rely on maintenance of market share to prevent cheating. For example, Alaouze, Watson, and Sturgess have constructed a triopoly model of wheat pricing that explicitly assumes a bounded price leader-follower relationship. Within the price bounds, it is assumed that members maintain a constant market share and respond to cheating in a manner that will preserve this share. Recall, however, that the triopoly model of Alaouze, Sturgess, and Watson does not have the same objective function as the present cartel, and hence, the arguments above about the applicability of Osborne's rule to the problem at hand are not necessarily equivalent to those necessary for their model.

[6] Here again, it is assumed that firms are profit maximizers (see footnote 1). If some members of the cartel are government-owned corporations with a different objective function, say revenue maximization, these arguments must be modified somewhat.

porters forming a cartel to exploit potential monopoly profits that might exist in the international grain market. The present paper has analyzed the impacts of the formation of such a cartel with the explicit objective of joint profit maximization. It has been demonstrated that without some fairly strong assumptions, e.g., substitutability, fluctuations in international demand might evoke different responses on the part of the cartel profits and the farm level price for wheat. Furthermore, if substitutability in factor demand is assumed, then one can show that an increase in international demand could lead to a drop in cartel price and a rise in the price of wheat as paid to the farmer. The restrictive nature of these assumptions, however, illustrates the difficulty of establishing what appears to be a fairly intuitive result. More specifically, it has been demonstrated that if all factor supplies are completely inelastic, the response of factor prices to an increase in w will be positive and unit elastic. Further, if substitutability in factor demand and own-price dominance of cross-price effects is assumed, then an increase in w will lead to an increase in all factor prices. An increase in w will always lead to an increase in cartel profits but, a priori, will be associated unambiguously with a rise in cartel price if the differential effect $\frac{\partial R}{\partial \mathbf{v}_j}$ is positive for all j.

Thus, it has been demonstrated that even if cartel profits rise, there is no reason to expect that the price of wheat at the farm level necessarily will rise. Hence, the economic surplus captured by forming a cartel may not filter down to the farm level. Politically, of course, this would be hard to justify. However, among several alternatives, it is always possible to levy a straight percentage tax on profits to capture some of this surplus and redistribute it to farmers. The feasibility of such a policy action is, of course, another question. The track record of past efforts at this type of taxation is not encouraging. Consequently, it may be necessary for the governments involved to intervene more directly in the marketing and production process if a portion of this economic surplus is to be captured for the factors. The obvious implication of this result is that there may well be cases where government-operated export cartels, which consider consumer and producer returns in addition to the level of cartel profits, would be appropriate. This, of course, is a normative question and remains outside the framework of this analysis. Further research, both theoretical and empirical, along these lines is needed.

Because a cartel must survive to be of any long-run consequence, some time also has been spent showing that the cartel under analysis is capable of overcoming some of the divisive factors that ordinarily might lead to a breakdown of the cartel. In the main, these results follow directly from Osborne's quota solution to cartel problems.

The discussion of Osborne's quota rule and its application to the problem at hand, however, raises an interesting issue. If Osborne's quota rule is used to impose a solution on the members of the cartel, i.e., specify a particular level of sales for each firm, it follows that each firm will not necessarily face a differentiable demand relationship. This is important because it implies that if the cartel in question is itself a "firm" that is operating in a larger cartel (say, a national grain-exporting company in a multicountry cartel) then there will not necessarily exist a differentiable relationship between price and quantity for this minicartel if the larger cartel is implementing Osborne's quota rule. Hence, some of the specific results of the preceding analysis may be valid only where the cartel in question does not participate in a larger cartel.[7] This, however, does not change the general conclusion that formation of a wheat-exporting cartel need not lead to higher farmgate prices and a positive correlation between cartel profits and the farmgate price of wheat. Obviously, the above model serves as a counter-example to such a conclusion.

Although it has not been discussed explicitly, there is the definite possibility that a good part of the potential monopoly profits could be erased by monopsony power on the part of the importers. Indeed, this is the gist of the recent paper by Carter and Schmitz, who demonstrate that importers may be exploiting their monopsony situation. If correct, the Carter-Schmitz result is really a further argument for the formation of some type of cartel or cooperative export arrangement, since not cartelizing leaves the exporters in the rather uncomfortable position of knowing that they are being exploited while not doing anything about it. Forming a cartel at least would help to counteract some of the bargaining power of the importers. Of course, this leads to a bilat-

[7] We would like to thank Chris M. Alaouze for bringing this point to our attention.

eral monopoly situation which is outside the scope of the present paper but should be the topic of further research, perhaps along the lines suggested by McCalla (1977).

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References

Alaouze, Chris M., A. S. Watson, and N. H. Sturgess. "Oligopoly Pricing in the World Wheat Market." *Amer. J. Agr. Econ.* 60(1978):173–86.

Bieri, Jurg, and Andrew Schmitz. "Market Intermediaries and Price Instability: Some Welfare Implications." *Amer. J. Agr. Econ.* 56(1974):280–5.

Carter, Colin, and Andrew Schmitz. "Import Tariffs and Price Formation in the World Wheat Market." *Amer. J. Agr. Econ.* 61(1979):517–22.

Carter, Colin, Nancy T. Gallini, and Andrew Schmitz. "Producer-Consumer Trade Offs in Export Cartels." *Amer. J. Agr. Econ.* 62(1980):812–18.

Diewert, W. E. *Duality Approaches to Microeconomic Theory*. Tech. Rep. No. 281, Econ. Series, Institute for Mathematical Studies in the Social Sciences, Stanford University, Oct. 1978.

Graybill, Franklin A. *Introduction to Matrices with Applications in Statistics*. Belmont, Calif.: Wadsworth Publishing Co., 1969.

Holahan, William L. "Cartel Problems: Comment." *Amer. Econ. Rev.* 88(1978):942–46.

McCalla, Alex F. "A Duopoly Model of World Wheat Pricing." *J. Farm Econ.* 48(1966):711–27.

———. "Strategies in International Agricultural Marketing: Public vs. Private Sector." Paper presented at the Symposium on International Trade and Agriculture, Tucson, Ariz., 17–20 Apr. 1977.

Osborne, D. K. "Cartel Problems." *Amer. Econ. Rev.* 66(1976):835–44.

———. "Cartel Problems: Reply." *Amer. Econ. Rev.* 68(1978):947–49.

Takayama, Akira. *Mathematical Economics*. Hinsdale, Ill.: Dryden Press, 1974.

Academic Freedom and Peer Reviews of Research Proposals and Papers

R. L. Berry

Academic freedom—the freedom of professional persons to present unpopular views—can exist only when there is freedom from severe sanctions such as censorship of research proposals and papers. Peer reviews are invaluable to researchers struggling to improve their work. They are also invaluable to administrators who must allocate limited funds and journal pages among competing researchers. However, evidence indicates that some administrators use peer criticisms to justify the suppression in whole or part of unpopular proposals and papers. Such prior restraint is censorship unless the administrators can prove that it is justified because of gross incompetence or financial exigency.

Key words: academic freedom, censorship, peer reviews, research papers, research proposals, responsibilities.

For excellence in teaching and research, two things are needed: excellent professional workers and excellent working conditions. Of the working conditions, one of the most difficult to achieve and maintain is academic freedom—also sometimes called intellectual, individual, or scientific freedom. But what is academic freedom? What are its limits? If there are limits, how can they be set? By whom?

Special interests—powerful persons or groups on or off the campus—often limit academic freedom. They may limit by their mere presence, but sometimes they take direct action to intimidate administrators who, in turn, limit academic freedom. Political scientist Charles Hardin found that special interests often set such limits in the U.S. Department of Agriculture (USDA) and the State Agricultural Experiment Stations (SAES) between 1930 and 1955. In 1972 a Committee on Research, created by the National Research Council of the National Academy of Science, found in both USDA and SAES a "shocking amount of low quality research," which it held was due largely to heavy-handed bureaucratic administration that was reducing "individual freedom, motivation and creativity" (p. 15).

The Committee recommended increased use of peer review committees for proposed research similar to those used for awarding research contracts or grants and the review of journal papers. Partially in response to this criticism, the USDA through its Scientific and Educational Administration-Cooperative Research (SEA-CR) has asked all SAES to arrange peer reviews for all research proposals to be submitted to it for some of the federal research funds which it administers. Because the peer reviews are to be similar to those used for the review of research papers, they may be discussed together.

Granted that a peer review is a valuable research tool, is it not a two-edged sword? Is it not possible that peer criticism may be used by timid or fearful administrators to suppress certain kinds of research and suppress in whole or in part research reports or papers? If so, what safeguards are needed to make sure that peer reviews increase rather than decrease academic freedom? My purpose is to answer these questions by critically reviewing the literature concerning (*a*) the limits of academic freedom, (*b*) some legitimate uses of peer review committees, and (*c*) the dangers to academic freedom when peer reviewers are asked to evaluate critically in-house research proposals or papers.

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Academic Freedom: What Are Its Limits?

The word freedom means without limits bounds. But what is academic freedom? It is considerably more than what is usually meant by intellectual freedom. It gives scholars and scientists freedom to seek and report the truth as they see it to students and the public in both oral and written form and is made possible by freedom from sanctions which may be imposed by powerful persons or groups on or off the campus. This definition is a restatement of definitions by others. Because of their importance, these definitions also are given here.

Philosopher Arthur Lovejoy declares that "academic freedom is the freedom of the teacher or research worker in higher institutions of learning to investigate and discuss the problems of his science and to express his conclusion whether through publication or in the instruction of students without interference from political or ecclesiastical authority, or from the administrative officials of the institution in which he is employed unless his methods are found by qualified bodies in his own profession to be clearly incompetent or contrary to professional ethics" (p. 384).

Economist Fritz Machlup declares academic freedom exists when there is "protection from" powerful persons or groups on or off the campus who would use restraints, pressures, or sanctions to create in the minds of researchers, teachers, and students "fears and anxieties" that may inhibit their freedom to seek the truth and discuss, teach, or publish "whatever opinion they may have reached" (p. 178).

Philosopher Sidney Hook states that "academic freedom . . . is the freedom of professionally qualified persons to inquire, discover, publish and teach the truth as they see it in the fields of their competence." Hook makes clear that this "freedom . . . to" can exist only when there is freedom from administrative controls when he declares "it is subject to no control or authority except the control . . . of . . . rational methods" (p. 34). Hook also emphasizes that professionals must have the freedom to present the truth "as they see it"—not as others see it. Furthermore, he insists they have "the right to be wrong"—the right to be honestly mistaken; that without this right there can be no academic freedom (pp. 36–7).

In 1973 the Committee for Economic Development (CED) assembled a distinguished panel consisting of college administrators and business leaders who defined academic freedom as "the principle that individuals, both faculty and students, should not be inhibited or restrained by external forces or threat of censure in the search for knowledge and the presentation of information and ideas whether in the classroom, in publications, or through other means of communication" (p. 56).

Perhaps the most widely accepted definition of academic freedom is provided by the 1940 *Statement of Principles on Academic Freedom and Tenure* jointly developed by the Association of American Colleges and the American Association of University Professors (AAUP, 1977a), which has now been endorsed by 107 professional organizations. The 1940 *Statement* declares that "the teacher is entitled to full freedom in research and the publication of the results . . . freedom in the classroom in discussing his subject . . . [and] when he speaks or writes as a citizen he should be free of institutional censorship or discipline" (p. 2). There are some cautionary words: "He should be careful not to introduce into his teaching controversial matter which has no relation to his subject"; but a note declares that "the intent of this statement is not to discourage what is 'controversial.' Controversy is at the heart of the free academic inquiry which the entire statement is designed to foster" (p. 3). Still, to avoid unnecessary controversy "he should at all times be accurate, should exercise appropriate restraint, should show respect for the opinions of others and should make every effort to indicate that he is not an institutional spokesman" (p. 2).

The 1940 *Statement* declares that all faculty members, whether tenured or not, should have these freedoms and they should not be dismissed or sanctioned for exercising them. Furthermore, to help protect academic freedom, faculty members who have completed a probationary period should be granted permanent or continuous tenure which may be broken only for "adequate cause" in a due process hearing such as provided for in AAUP's RIR—"Recommended Institutional Regulations on Academic Freedom and Tenure" (AAUP 1977b). When tenure is granted, the burden of proof regarding professional competence shifts from the faculty member to the administration. When there is clear evidence of professional incompetence or unfitness, this burden is not heavy. Only when there is considerable doubt does it become heavy—as it must be if tenure is to protect academic freedom.

Unfortunately, academic freedom can be destroyed by lesser sanctions than summary dismissal. When nontenured professors present unpopular views, they may not be reappointed. Also they may be punished by denial of promotion or normal pay increases. Finally, their proposals and papers may be suppressed or censored. But, when the professor can show that a "motivating factor" for dismissal or other sanctions may be a violation of civil rights, then the U.S. Supreme Court (*Mount Healthy* v. *Doyle* 1977) has held that those responsible must show by a "preponderance of the evidence" that the action was justified for other lawful reasons (Rabban, pp. 4–6).

Freedom to present unpopular views is not a popular concept. CED's distinguished panel of college presidents and trustees declared that "among major distinctive problems . . . of colleges, none is more critical than the preservation of academic freedom" and hence called for "policies and practices that will protect responsible intellectual freedom" (p. 24). The word "responsible" suggests limits. What limits? One limit is serious misconduct which violates the 1940 *Statement*'s academic responsibility provisions quoted above. Even when the administration holds that such violation by a professor justifies dismissal, it must prove its case in a due process hearing if its assurance of academic freedom is to be trusted. This the University of Illinois failed to do in 1960 when a biology professor wrote a letter to the student newspaper condoning premarital sex. AAUP's Committee A held that institutions might apply sanctions for misconduct if shown by a due process procedure to be warranted. Unfortunately, the University did not provide a satisfactory hearing and hence was censured.

What kind of a violation would justify sanctions? Ralph F. Fuchs, law professor, and former General Secretary of AAUP followed the 1940 *Statement* when, in a comment on the Illinois case, he declared "A violation may consist of serious intemperateness of expression, intentional falsehood, incitement to misconduct or conceivably some other impropriety of circumstance. It may not lie, however, in the error or unpopularity, even though gross, of the ideas contained in an utterance" (pp. 41–2).

Freedom, Responsibility, and Neutrality

Academic freedom like any other freedom creates responsibilities. The AAUP Statement of Professional Ethics declares that the professor's "primary responsibility to his subject is to seek and state the truth as he sees it" (AAUP 1977d, p. 65). But when the professor's views are controversial or unpopular, administrators come under heavy pressure to dismiss or apply other sanctions which would violate academic freedom.

To avoid this situation some administrators hold that professors must be neutral—they must present only the issues and the facts and not their conclusions or opinions about their significance. Administrators who hold this view sometimes charge that professors who incur the wrath of powerful people or groups have failed to observe a second responsibility, which is "to exercise critical self-discipline and judgment in using, extending and transmitting knowledge" (AAUP 1977d, p. 65). In some cases this may be true, but the burden of proof of such a charge must be on the administration. Otherwise the freedom to present controversial conclusions, views, and opinions evaporates.

Some people believe that teachers and researchers can handle any controversial subject simply by presenting "issues" and "facts" and then leaving hearers or readers to draw their own conclusions. Unfortunately, both issues and facts are often matters of opinion. Hence this does not resolve the difficulty. Furthermore, the refusal of an expert to take a stand is an acceptable position only when he is genuinely uncertain about what should be done. To do otherwise is to raise the question as to his professional integrity. Moreover, when academic freedom exists he must use it or lose it.

Sometimes, of course, there is nothing to lose. Some administrators limit freedom to popular conclusions, views, and opinions—a freedom that exists in the most repressive nations and institutions, for example, prisons.

Thus, institutional neutrality is essential if the teacher or researcher is to have academic freedom. This means that the faculty, its committees, and its administrators and editors, despite strong feelings and opinions they may have about the issues, must be officially neutral. If they are not officially neutral, academic freedom is impossible. As Solberg has emphasized, "the norm of neutrality is an essential safeguard of academic freedom" (p. 13).

In 1934, A. Lawrence Lowell, professor of law and then president of Harvard University, wrote, "If the university or a college censors

what its professors may say, if it restrains them from uttering something it does not approve, it thereby assumes responsibility for that which it permits them to say. This . . . is a responsibility which an institution of learning would be very unwise in assuming." He concludes that because "there is no middle ground," the university should be neutral (Taylor p. 396).

But can the university really be neutral? Some critics have pointed out that neutrality is also a position. Indeed it is, but it is the only position that permits full academic freedom and avoids censorship. Recently Harvard University has been urged to sell its stock in corporations doing business in South Africa because of its racial policies. President Derek Bok has been criticized for his refusal to do so, but it should be remembered that the university consists of all of its scholars and scientists. If they value academic freedom, they should not attempt to judge such issues by the ballot box nor permit their administrators to take action pro or con in their name. Either way, academic freedom in this area would be destroyed. Unpopular positions would be beyond the pale.

It is also argued that the university cannot afford to be neutral—cannot afford full or unlimited freedom for fear that professors will publish errors that will destroy not only their own reputations but also that of their colleagues, their department, college, and institution. Hence it is argued that peer reviewers should not only help the author avoid errors of omission or commission but also should be able to suppress the work in whole or part until it meets with their approval. Because this is the central issue of this paper, further discussion will be delayed until the legitimate functions of peer review committees have been critically examined.

Peer Review Committees: Their Legitimate Uses

The word peer means equal, not superior. Yet, some peers also are made superiors. For example, college administrators often are chosen for their excellence as peers and they do not lose their professional competence the moment they are appointed administrative superiors. In like manner, peer review committees also may become superiors when they are given certain administrative duties. Why should they be given such duties? First, because they are the most competent people available to make recommendations concerning teaching, research, and other educational matters. Second, because they must cooperate if administrative decisions are to be carried out. Third, because this cooperation is more likely to be secured when decisions are jointly made.

These reasons support the principle of "shared authority" found in the "Statement on Government of Colleges and Universities," which would give the faculty the major voice "in such fundamental areas as curriculum, subject matter and methods of instruction, research, faculty status and those aspects of student life which relate to the educational process" (AAUP 1977c, p. 43). For example, peer review committees should be asked to make recommendations when decisions must be made to appoint, reappoint, promote, grant tenure, or dismiss faculty members. Furthermore, administrators should reject peer recommendations "only in exceptional circumstances, and for reasons communicated to the faculty" (p. 43). Even then, when possible, the review committee should be given an opportunity to reconsider before a final decision is made. Thus, faculty or peer committees may be used legitimately whenever administrative decisions must be made about the allocation of educational resources.

Research Grants and Journal Space

Thus, when institutions make grants of research funds or journal space, they may properly use peer review committees to referee the competition. Because funds and pages are limited, it often happens that some research proposals and papers must be rejected. While both can be rejected for reasons that violate academic freedom, this does not necessarily follow peer review. Indeed, peer reviewers can do much to protect academic freedom. Because of their expertise, they are better qualified to recognize innovative or creative research and should support it.

Unfortunately, the best qualified peers may also be the researcher's competitors. Hence prejudice and jealousy may lead to rejection and violation of academic freedom (AAAS p. 8). Here the rule should be this: If a researcher alleges that his proposal or paper was rejected for reasons that violate academic freedom, he should be responsible for stating the reasons and the evidence that supports them. If he

makes a *prima facie* case, those responsible for rejecting the paper should then be required to show by a preponderance of the evidence that the rejection was for other valid reasons (AAUP RIR Rule 10, p. 21, and Rabban, pp. 4–6). This rule places a heavy burden on any researcher who believes that he was denied a research grant or journal space for reasons that violate academic freedom. While this burden is heavy, it must be heavy if administrators, with or without the aid of peer reviewers, are to have freedom to achieve excellence in research and publication.

To summarize, peer committees may legitimately be used to assist administrators in their efforts to manage wisely the limited resources at their disposal but this does not include their use to suppress or censor unpopular or controversial views and opinions.

Peer Reviews of In-House Research

What are the legitimate uses of peer review committees when there is in-house research and in-house publishing facilities? This is the crucial issue. Both the USDA and the land-grant institutions have funds to conduct in-house research and publish the results. Peer review committees can be used legitimately to help choose the areas of research and to assign them to researchers just as they can be used legitimately to decide what subjects shall be taught and who shall teach them.

The task of the administrator is to allocate wisely the available resources for teaching and research, and he may legitimately use peers to help make these decisions. However such decisions are made, it would be a gross misallocation of research funds to secure competent research workers, provide them with research facilities, all at great cost and then not publish the results. Such action would be comparable to assigning a teacher to lecture to a class but then barring him from the classroom. Publication is one way of communication and a lecture is another.

Thus, research institutions may appoint researchers and assign research projects, but their administrators should not interfere with research methodology or censor the findings and conclusions. They will be concerned about the quality of research and it would not be improper to ask the researcher to submit his procedures and papers to peer reviewers for whatever help they can provide. But it would be most improper for administrators to insist that researchers accept the reviewer's criticism before the project is funded or the paper is published. Such prior restraint is censorship—and therefore a violation of academic freedom—unless the institution can show that such action is justified by gross incompetence or an extraordinary financial exigency. In either case the burden of proof should be on the administration, and peers not previously involved should be asked to evaluate the evidence (AAUP RIR Rule 10, p. 21, and Rabban, pp. 4–6).

After an administrator, with or without peer assistance, has made a teaching or research assignment, his responsibility ends and the professor's begins. The professor is the administrator of his classroom and his research project. As administrators, professors also may seek the advice of peer reviewers. While peers should have full freedom to evaluate critically and make recommendations, the author also should have full freedom to accept or reject them. If he does not, there is a violation of his academic freedom.

Administrators have reasons for their reluctance to grant researchers full freedom as to methodology because it may lead to unpopular findings, conclusions, views, and opinions. As a result, special interests may be offended and public funds reduced. Funds must be secured to finance the institution. To secure additional funds, people need to be assured that present funds are being spent wisely. Senator William Proxmire appeals to taxpayers when he makes his "golden fleece" award for research which he believes is fleecing the public. While he may hit the mark, there is danger that his attacks may destroy more than it conserves. Academic freedom to do innovative or creative research may be chilled. But the Senator is not alone. Every state has special interest groups who wail in anguish whenever their golden sheep are threatened by research proposals or papers. Hence, administrators are under heavy pressure to suppress both.

Peer and Public Pressures

In large private universities the greatest threat to academic freedom may originate with peers. For example economist George Stigler, University of Chicago, has said that "academic freedom in its true meaning—the freedom to say unpopular things—is in its present low estate because we professors . . . [exercise] strong sanctions against the hiring and

promotion of holders of unpopular views" (last page). Hence many professors are afraid to express such views, especially in writing.

Kingman Brewster, Jr., former president of Yale University, agrees: "In strong universities assuring freedom from intellectual conformity coerced *within* the institution is even more a concern than is the protection of freedom from external interference" (his emphasis). Tenure, he points out, provides some protection, but even so "fear of failure in the eyes of the peerage inhibits some . . . . Too many seek the safe road of detailed elaboration of accepted truth rather than the riskier paths of true exploration which might defy conventional assumptions" (p. 382).

But in public universities and research institutions, the professor's academic freedom is under heavy pressure primarily from off-campus special interest groups. Perhaps the best-known example is the 1943 butter-margarine controversy at Iowa State College, now Iowa State University. This controversy reveals not only the pressures which special interests can exert on academic freedom but also the misuse of review committees to justify censorship (Hardin, Weir).

In 1943 Iowa State was forced by Iowa dairy interests and the Iowa Farm Bureau to withdraw its Pamphlet Number 5, "Putting Dairying on a War Footing." In this pamphlet its author, agricultural economist O. H. Brownlee, had stated that properly fortified margarine "compared favorably" with butter. The president of Iowa State, after making a defense of academic freedom, agreed that if there were errors, they should be corrected. But who was to determine what errors existed? This task was assigned to a committee of six dairy leaders and six professors. Three of the professors were agricultural economists (T. W. Schultz, G. S. Shepherd, and W. G. Murray). The committee found what it believed to be some errors, ambiguities, and lack of adequate documentation. Hence, it recommended that the pamphlet be retracted and completely revised under the direction of a committee composed of dairy and farm leaders. In the meantime, the president had had the pamphlet reviewed by the director of agricultural relations and by professors of dairy husbandry, dairy industry, animal husbandry, and home economics. This committee was also critical of the pamphlet.

As a result, the president retracted the pamphlet and announced that it would be revised in cooperation with the dairy interests. Then T. W. Schultz, head of the economics and sociology department, in a letter of resignation, charged that the administration was violating academic freedom not only in the margarine controversy but by its (*a*) refusal to publish an article on the feed grain situation in the *Iowa Farm Economist,* (*b*) refusal to approve publication of a manuscript on wartime farm food policies by John Vieg and William H. Nicholls, (*c*) abrupt termination of a radio program by a social science staff member, Bryce Ryan, and (*d*) refusal to permit the department to use any further funds from a $10,000 research grant made by Rockefeller Foundation (Hardin, pp. 115–20; Russell, Sect. 4, p. 1; Weir, pp. 98–105). When the president was asked about these charges he replied, "I have never questioned the right of the staff member to write and publish whatever he pleases but I do reserve the right of decision of the propriety of having publication under the college signature" (Russell, Sect. 4, p. 1).

Within a week the president issued a policy statement which included these points: "[1] that over the past 25 years wise and effective procedures and controls have been developed. . . . [2] that those controls provide every reasonable freedom within the accepted limits of our activities [3] that those controls have proved to be entirely sound and constructive [4] that they have served as safeguards to members of the staff and to the many groups . . . with whom we have worked and will continue to work." The statement concluded by declaring that "the fundamental right of the college staff to publish on his own responsibility has never been in question. But at the same time the college has the right and obligation to see that all publications issued under the official sponsorship and signature of the college have been submitted to the approved methods of review and criticism" (*Des Moines Tribune,* 25 Sept. 1943, p. 1).

Thus the president, by both his actions and words, made it abundantly clear that, in his view, academic freedom does not require institutional neutrality, that the institution must provide not only for peer but also nonpeer reviews, and that these reviews may be used to justify the suppression in whole or part of research proposals and papers. This is, of course, censorship; and censorship is a violation of the widely accepted meaning of academic freedom. Given the president's limited

view of academic freedom and the power of pressure groups, it is not surprising that Iowa's state board of control found "after thorough and intensive consideration . . . that the charge of the violation of the fundamentals of academic freedom in all particulars is without foundation in fact" (*Des Moines Tribune*, 5 Nov. 1943, p. 1; Hardin, p. 121). Hardin concluded that what happened at Iowa State was "by no means unique." He found administrators at other institutions in fairly general agreement that the butter-margarine issue was "too hot to handle," and hence their research and extension workers were induced to keep hands off. By doing this, they were violating academic freedom. Under these circumstances it is not surprising that most elements in these institutions lined up with the dairy interests.

Only when administrators are neutral do professors have full freedom to seek and report the truth as they see it (Solberg, Taylor, Friedland). But such neutrality is difficult to maintain when powerful persons or groups have vested interests. These interests are almost always found when federal or state funds are being allocated but they also exist for private funds. "Patrons of university activities are not renowned for their neutrality when it comes to economic research," says Schultz in a recent unpublished paper (p. 2). He notes that "the now fashionable concepts of targeted and mission-oriented research are as a rule subterfuges for intrusion. Peer review of economic research proposals . . . is a convenient device of obtaining sufficient differences in evaluations to give the administrator . . . a free hand in deciding whether or not to approve the proposal" (p. 12). Also, administrators are under heavy pressure to use peer reviews of research papers to justify the suppression in whole or part of findings and conclusions with which they or other powerful persons or groups may disagree.

Administrators may agree with Lowell's view quoted above, that once they accept responsibility for what professors may not say, they also accept responsibility for what they do say. However, this presents them with no serious problem. They can use peer reviews to assist in the suppression in whole or part of unpopular research proposals and papers and they are eager to accept credit for any noncontroversial or popular conclusions of their "team." These popular "products" make it easier for administrators to secure support for more research and helps them achieve professional advancement. In some cases this may even maximize the public interest just as some monopolies do. But as noted, a NRC-NAS Committee found that there was much low quality research in both USDA and the SAES which appeared to be due to heavy-handed administration that was reducing "individual freedom." The Committee proposed that this situation be corrected by peer reviews of research proposals.

Perhaps as a result of this criticism, USDA has made some changes. SEA-CR has requested all SAES to make peer reviews of all new research proposals to be funded through its office. By 1978, SEA-CR had "cleared" the peer review systems of forty SAES (SEA-CR Exp. Sta. Letter, 1448, 7 Apr. 1978). The South Dakota station's system, entitled "Peer Review of Research Proposals," requires that proposals be approved by two or more peer reviewers before administrative approval and submission to SEA-CR. The reviewers are required to report their criticisms in writing and sign their statements. Then the researcher must respond to the reviewers recommendation and submit both to the administrator along with the comprehensive project proposal. Thus, peer reviewers' criticisms are available to justify censorship.

An alternative which avoids censorship would be to require the researcher to attach a statement to his project proposal or paper attesting that an earlier draft had been critically reviewed and the criticisms had been carefully considered in preparing the present draft. This alternative would allow peers full freedom to criticize and suggest changes and the researcher full freedom to accept or reject them—just as he must accept or reject any other information.

To avoid censorship, funds should be available to publish the results of in-house research; but if they are not, the researchers should be informed before starting the research that publication must be secured elsewhere. Generally, it is a gross misallocation of resources to fund research but not publication of the results. Quality of research and research papers can be maintained by appointing competent researchers, by peer reviews, and by editorial services.

Summary and Conclusion

Excellence in teaching and research can be achieved by appointing the most competent

persons available and by giving them good working conditions. Of these conditions the most important is academic or scientific freedom to seek and to report what they believe to be true, made possible by freedom from dismissal or other severe sanctions that may be urged by powerful persons or groups on or off the campus.

Administrators may legitimately use peer review committees to help them wisely allocate available resources, including the refereeing of competitive research proposals and papers for limited funds or journal pages. When funds or pages are limited, peer review committees can provide invaluable help in selecting the best for acceptance. The choice should be made on the excellence of the proposals or papers—on their contribution to knowledge. But there is the ever-present danger that proposals and papers may be rejected because they are unpopular with reviewers whose golden sheep are being sheared or because the proposals and papers are likely to be controversial or unpopular with powerful persons or groups.

Administrators of in-house research and publishing facilities such as USDA and the State Agricultural Experiment Stations also may insist that their professionals submit their research proposals and papers to peer reviewers before they are funded or published. Peers should exercise full academic freedom in making their reviews but their suggestions and criticisms should go directly to the researcher. If they also go to the administrator, he may be tempted to reject the proposal or paper until at least a majority of the reviewers approve. When this happens the peer review committee has become, perhaps without its knowledge or consent, a board of censors—a means of suppressing unpopular or controversial research proposals and papers, a means of violating academic freedom so necessary for creative and innovative research and teaching.

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References

American Association for the Advancement of Science (AAAS). *Scientific Freedom and Responsibility.* Washington, D.C., 1975.

American Association of University Professors (AAUP). "Academic Freedom and Tenure: The University of Illinois." *AAUP Bull.* 49(1963): 25–43.

———. "1940 Statement of Principles on Academic Freedom and Tenure." *AAUP Policy Documents and Reports.* Washington, D.C., 1977a.

———. "Recommended Institutional Regulations on Academic Freedom and Tenure." *AAUP Policy Documents and Reports.* Washington, D.C., 1977b.

———. "Statement on Government of Colleges and Universities." *AAUP Policy Documents and Reports.* Washington, D.C., 1977c.

———. "Statement of Professional Ethics." *AAUP Policy Documents and Reports,* Washington, D.C., 1977d.

Brewster, Kingman, Jr. "On Tenure." *AAUP Bull.* 58(1972):381–83.

Committee for Economic Development (CED). *Management and Financing of Colleges.* New York, 1973.

Friedland, William H. "Social Science and Humanistic Considerations in Agricultural Research." *Proceedings of a Conference on Outreach Programs of the Land Grant University: Which Publics Should They Serve?* Kansas State University, 1978.

Hardin, Charles M. *Freedom in Agricultural Education.* Chicago: University of Chicago Press, 1955.

Hook, Sidney. *Academic Freedom and Academic Anarchy.* New York: Cowles Book Co., 1970.

Lovejoy, Arthur O. "Academic Freedom." *Encyclopedia of Social Science* 1(1930):384.

Machlup, Fritz. "Some Misconceptions Concerning Academic Freedom." *AAUP Bulletin* 41(1955):753–84.

National Academy of Science, National Research Council. *Report of the Committee on Research Advisory to the U.S. Department of Agriculture.* Washington, D.C., April 1972.

"Policy Statement Issued by Friley." *Des Moines Tribune,* 25 Sep. 1943.

Rabban, David M. "Mixed Motives in Faculty Terminations." *AAUP Academe,* June 1977, pp. 4–6.

Russell, J. S. "Freedom of I.S.C. Curbed, Schultz Says." *Des Moines Register,* 19 Sep. 1943.

Schultz, Theodore W. "Distortions in Economic Research." Unpublished paper for Social Science 50th Anniversary Celebration, University of Chicago, 5 Dec. 1979.

Stigler, George J. "Viewpoint: Thought Control on the Campus." *Chronicle of Higher Education,* 13 Aug. 1973.

Solberg, Winton U., and Donald N. Koster. "On Institutional Neutrality." *AAUP Bull.* 56(1970):11–13. See also, "Further Comments on . . . ." *AAUP Bull.* 56(1970):123–129.

Taylor, John F. A. "Politics and the Neutrality of the University." *AAUP Bull.* 59(1973):389–96.

Weir, Muriel Ann. "Pamphlet No. 5 and the Freedom to Publish at Iowa State College." M.S. thesis, Iowa State University, 1976.

Social Costs and Benefits from Component Pricing of Soybeans in the United States

Nelson J. Updaw

The recent development of near-infrared reflectance instruments allows grain traders to measure chemical composition when grain is sold. This study provides estimates of the social benefits and costs of such measurements to be used in the pricing of soybeans. The economic model integrates a production possibilities frontier with the demand for two chemical characteristics, oil and protein content. The results indicate that it is unlikely that the benefits of pricing soybeans on the basis of component measurement would have exceeded measurement costs.

Key words: component pricing, consumers' surplus, elasticity of transformation.

Agronomic practices which are expected to maximize profits for producers tend to vary among regions of the United States. Locational differences in the employment of factors of production, combined with differences in the marginal productivity of inputs used at every location, ensure that the product characteristics of most commodities will vary. For those commodities in which variation of product characteristics is of major concern, market traders have developed grading standards that define product "quality." Each grade specifies for selected characteristics a bound which cannot be exceeded, thereby providing market participants an indication of the utility to be obtained through the consumption of any unit. Established standards are intended to segregate each commodity so that there exists an identifiable relationship between each unit's grade assignment and the value of its characteristics. Price differentials among grades reflect differences in the market-clearing prices for highly substitutable goods.

Because grades provide information to market participants, they may be viewed as an input to the marketing process (Kihlstrom). Unless grading procedures are prescribed by law, each characteristic observed in the grading process must be expected to provide marginal benefits to traders that exceed or equal marginal measurement cost.

Some characteristics included in the official grading standards may go unmeasured; in addition, those characteristics observed need not include the characteristic(s) of greatest interest to certain traders. If a particular characteristic (or set of characteristics) determines the marginal value product of an agricultural commodity but is extremely costly (or impossible) to observe at the time of sale, then it is conceivable that alternative characteristics known to be correlated with the characteristic of interest will be substituted for it in the grading standards. Unless the correlation is perfect, a grade assignment based upon the proxy characteristics may provide an imperfect assessment of the value of the unit to the purchaser.

Some observers have criticized grading procedures used in the United States because those characteristics measured frequently provide an inaccurate estimate of marginal value product (e.g., Graf). Furthermore, the size of the divergence between estimated marginal value product and market price can be sizeable; for example, Ladd and Martin have demonstrated that corn graded as low as standard may have characteristics valued more highly by some purchasers than those of corn which meet the requirements for U.S. No. 1. It has been suggested that price determination based upon grades be replaced by a system in which the price of every commodity be set in accordance with the sum of the value of its

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separate components. This may be referred to as component pricing (Perrin). This concept is a logical refinement of grade determinant pricing; rather than establish a price on the basis of measurements that fall into specified ranges, the price of an unprocessed commodity would be set according to point estimates of the values of all measured characteristics. Proponents claim that society would benefit from component pricing because (*a*) there would be a reduction in, or perhaps the elimination of, the risk now borne by commodity buyers of paying a price which exceeds marginal value product; and (*b*) producers would be provided an incentive to produce commodities the characteristics of which possess marginal social benefits that exceed or equal marginal social costs.

Because market traders are free to establish grading schemes for most commodities, component pricing will not replace pricing by grades until market participants are convinced that component pricing is the more profitable practice. This may occur through a reduction in the cost of component pricing, an increase in its expected benefits, or a combination of the two. The recent introduction of near-infrared reflectance (NIR) instruments may represent a technological change that will reduce the cost of component measurement sufficiently so that many grains may be priced according to measured chemical characteristics.

The purpose of this study is to estimate the social costs and benefits of the component pricing of soybeans. This crop was chosen because (*a*) there is a strong association between marginal value product and soybean oil and protein content (Updaw, Bullock, Nichols); and (*b*) representatives of grain companies have indicated that they have not included chemical content measurements in determining offer prices for various deliveries of soybeans.[1]

Approach of the Study

It will be assumed in this study that the only characteristics of interest to soybean traders are oil content and protein content and that the component pricing of soybeans will create an environment in which the price of each bushel of soybeans equals the value of the two processed commodities obtained from each bushel less a constant crushing margin. In addition, it will be assumed that the introduction of component pricing of soybeans will have no effect upon international trade or the year-to-year carry-over of the crop.

Rinne et al. have documented that NIR measurements of soybean oil content and protein content are highly correlated with those obtained through conventional laboratory tests when the NIR measurements are made by trained operators in a controlled environment. Therefore, the social cost of the component pricing of soybeans will be defined as the additional cost incurred by traders who measure soybean content, or the ownership and operating costs of the machines. It will be assumed that competition among buyers will prevent the occurrence of systematic misreadings of soybean composition and that all domestic transactions will be made on the basis of component pricing.

If component pricing is economically feasible, those soybean buyers who first employ the practice can increase profits in the short run by restricting their soybean purchases to those beans that possess above-average levels of desired characteristics. Those buyers who do not practice component pricing will face a reduction in the quality of soybeans made available to them and, consequently, a reduction in profits. However, in the long run the rate of return on investment for NIR instruments should be consistent with zero economic profits. Therefore, it will be assumed that the component pricing of soybeans will confer no lasting benefits upon grain traders and soybean processors. The social benefits of component pricing will be reaped by soybean producers and the consumers of soybean oil and protein.

Gross social benefits of component pricing will be measured as the sum of the estimated change of producers' surplus for soybean producers and the estimated change of consumers' surplus for domestic consumers of soybean oil and meal. It will be assumed that welfare losses borne by any group will be exactly compensated by gainers. Social costs will be subtracted from this sum to arrive at a conclusion of the desirability of component pricing of soybeans in the United States. If gross social benefits exceed estimated measurement costs, it will be concluded that component pricing would have improved social welfare; if the difference is negative, it will be

[1] Personal correspondence with author. It should be mentioned that each individual contacted expressed reservations concerning the use of NIR instruments, citing measurement costs and machine reliability as problems.

concluded that social welfare would have been reduced. Any inference regarding the effect of component pricing in the future must be tentative in nature, but estimates based upon recent experience ought to provide a reasonable indication of the magnitude and direction of welfare changes.

Economic Model

The model to be used in this study is that of perfectly competitive markets for the two characteristics (Perrin). Given a fixed set of resources to be applied in the annual production of soybean oil and protein and no externalities in production or consumption, the maximization of social welfare occurs when society is located on its production possibilities frontier and the marginal rate of substitution in consumption equals the marginal rate of transformation in production (Nicholson, p. 534). This is equivalent to the requirement that the price of protein relative to oil paid by consumers be equal to that received by producers.

If no attempt is made to price soybeans according to chemical composition, the implicit prices received by soybean producers for oil and protein are equal. The wholesale price of soybean oil paid by consumers, however, has tended to exceed the wholesale price of protein, as shown in table 1.[2]

The producer price of protein (P_1^p) and oil (P_2^p) are calculated as the sum of the average price received by farmers for soybeans and the average crushing margin earned by processors, divided by 31.6 pounds of useful product (10.8 pounds of oil and 20.8 pounds of protein). The consumer price of oil (P_2^c) represents the average annual wholesale price of crude soybean oil at midwestern mills. The consumer price of protein (P_1^c) is calculated as the average annual wholesale price of 44% protein meal at midwestern mills, divided by 0.44. These data suggest that the equilibrium which has persisted each year is similar to that depicted in figure 1.

[2] Oilseed buyers are known to record the chemical composition of soybeans purchased in various regions of the United States. This information should affect regional demands and may force prices to reflect the average chemical composition of soybeans in each region. The extent to which this practice affects the average national oil content and protein content is uncertain.

Table 1. Average Wholesale Prices of Soybean Oil and Protein in the United States, in Cents per Pound, 1961–75

Time Period	$P_1^p = P_2^{p\,a}$	P_1^c	P_2^c	P_1^c/P_2^c
1971–1975	18.26	16.93	20.84	.812
1966–1970	9.26	8.79	10.12	.869
1961–1966	8.79	8.17	9.96	.820
1966–1975	12.10	11.30	13.64	.828

Source: USDA *Agricultural Statistics*.
[a] P_1^p is producer price of protein; P_2^p, producer price of oil; P_1^c, consumer price of protein; P_2^c, consumer price of oil.

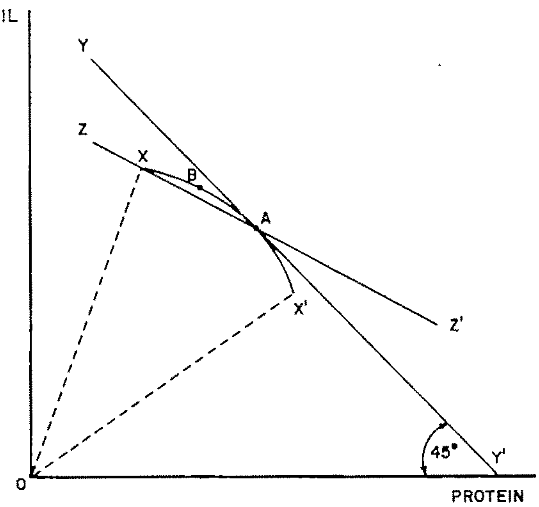

Figure 1. Market equilibrium

Let the function labelled OXX' represent the production possibilities frontier of soybean oil to protein, YY' the relative price ratio of protein to oil for the producing sector, ZZ' the relative price ratio for consumers and Point A the equilibrium quantities of oil and protein that are produced and consumed each year. Since oil and protein are produced jointly within each bushel of soybeans, it is impossible to specialize in the production of one good to the exclusion of the other; hence, the function OXX' does not span the entire quadrant (Heady, pp. 216–17).

With a constant, unitary relative price of protein to oil received by the producing sector, the point at which producers maximize profits is that combination of output at which the marginal rate of product transformation equals -1.0 (point A). Assuming that the transformation function is homogenous of degree one, proportional changes in the application of factors of production will shift OXX' but not change the ratio of oil to protein.

The implementation of component pricing is expected to alter the chemical composition of soybeans as producers respond to a change in the relative price ratio paid to them. Because the slope of ZZ' represents the relative price

of protein to oil paid by consumers, theory indicates that soybean producers can be expected to increase oil production and decrease protein production, *ceteris paribus*. If producer prices mirror those faced recently by consumers, annual output would rotate to point B of figure 1. However, as protein production declines relative to oil production, the relative price of protein to oil for consumers would rise. Equilibrium output would lie along OXX' between points A and B. A comparison of this point with point A provides an indication of the change in annual production and consumption attributable to the introduction of component pricing.

It is not possible to state a priori that the producing sector would experience an increase or decrease in welfare from the introduction of component pricing. If resource application is fixed, as assumed in this model, changes in total revenue will represent identical changes in producers' surplus. Because total revenue changes are determined by the demand for oil and protein, knowledge of these functions as well as the new equilibrium quantities is required to assess the benefits of component pricing to the producing sector.

Similarly, it is not possible to determine whether consumer welfare would increase or decrease from the introduction of component pricing. The direction of expected adjustment by producers indicates that oil consumers should benefit while consumers of protein should experience a decline in consumers' surplus. Whether the increase in consumers' surplus for oil consumers exceeds the decline in consumers' surplus in the protein market is an empirical question that cannot be answered without an estimate of the demand for the two goods and an estimate of the new equilibrium quantities.

The economic model, then, consists of a production possibilities frontier, the demand for oil and the demand for protein. By enforcing the restriction that the production frontier exhibit constant elasticity of transformation and the demand curves constant elasticity of demand, the model may be presented in the following six equations.

(1) production possibilities frontier:
$$X_2^{\phi_0} + \phi_1 X_1^{\phi_0} = K_0,$$

(2) profit maximization:
$$dX_2/dX_1 = -P_1^p/P_2^p,$$

(3) demand for protein:
$$X_1 = \epsilon_0 \, (P_1^c)^{\epsilon_1},$$

(4) demand for oil:
$$X_2 = \gamma_0 \, (P_2^c)^{\gamma_1},$$

(5) protein market equilibrium:
$$P_1^p = P_1^c, \text{ and}$$

(6) oil market equilibrium:
$$P_2^p = P_2^c,$$

where X_1 is quantity of protein produced and consumed each year; X_2, quantity of oil produced and consumed each year; P_1^p, real price of protein received by producers; P_2^p, real price of oil received by producers; P_1^c, real price of protein paid by consumers; P_2^c, real price of oil paid by consumers; and K_0, ϕ_0, ϕ_1, γ_0, γ_1, ϵ_0, and ϵ_1 are parameters to be estimated.

A solution of all six equations simultaneously provides a unique set of quantities and prices which corresponds to the equilibrium described by the neoclassical competitive model for a two-good economy. Through a series of successive substitutions, the six equations may be reduced to one nonlinear equation in which the equilibrium quantity of either good is determined by the parameters of the demand curves and the production possibilities frontier. Solving for protein (Updaw, pp. 28–29):

$$(7) \quad X_1 = (K_0 - \phi_1 X_1^{\phi_0})^{\left(\frac{\phi_0 - 1 - 1/\gamma_1}{\phi_0 D}\right)} (\phi_1)^{\frac{-1}{D}} (\gamma_0)^{\frac{1}{\gamma_1 D}} (\epsilon_0)^{\frac{-1}{\epsilon_1 D}},$$

where $D = (\phi_0 - 1 - 1/\epsilon_1)$.

Inserting X_1 in equation (1) provides the equilibrium quantity of soybean oil, X_2. X_1 and X_2 may then be inserted in their respective demand equations to obtain equilibrium prices for soybean protein and oil. Therefore, knowledge of the parameters of equations (1), (3), and (4) is necessary and sufficient to determine the equilibrium quantities and prices that would prevail if soybeans were priced in accordance with the value of their components. This solution may be compared with an observed equilibrium to determine the gross social benefits and costs of component pricing.

Demand for Oil and Protein

Because the mathematical specification of each demand curve is log-linear, observed average quantity demanded and real price over 1971–75 may be used with estimated price elasticity to derive the appropriate value of the constant term which precedes price in

each equation. Recent studies of the demand for oil and meal provide a rather wide range of estimated elasticities for the domestic demand for oil and meal (Updaw). Therefore, it became necessary to include the estimation of these elasticities in the study.

The demand models employed have been drawn from earlier studies (Vandenborre; Houck and Mann; Houck, Ryan, Subotnik). To allow comparisons to be made with these earlier studies, the quantity demanded, rather than price, was chosen as the endogenous variable in each equation. Exogenous variables included in the domestic demand for oil were the size of the domestic food-consuming population, real per capita income, and the annual quantities demanded of cottonseed oil, butter, and lard. In the case of the demand for protein, the exogenous variables were livestock population and the annual quantity demanded of substitutable feed (Updaw).[3] The results, corrected for positive serial correlation (Kmenta, pp. 278–82), are given in table 2.

The estimated elasticity of demand for protein is similar to those found earlier for soybean meal (Houck, Ryan, Subotnik). The elasticity estimate for oil, however, is significantly more inelastic than earlier estimates at the 95% level of probability. This may be attributed to the nonlinear specification of the demand curve as well as differences in the samples used in each study.

Incorporating these estimates with observed average quantities demanded and real prices over 1971–75 gives

[3] The formula used for converting substitutable feed to soybean meal equivalent is given in Houck and Mann, p. 46.

Table 2. Estimated Domestic Demand for U.S. Soybean Oil and Protein, 1947–1975

$$\ln X_{2t} = \underset{(4.36)^{a}}{-11.5035} - \underset{(0.06)}{0.0507} \ln P_{2t} \underset{(0.06)}{-0.0451} \ln(Q_{cotton}) \underset{(0.23)}{-0.0293} \ln(Q_{B\&L}) + \underset{(0.41)}{1.0951} \ln(real\ y) + \underset{(0.56)}{2.2365} \ln(pop) \qquad R^2 = .98$$

$$\ln X_{1t} = \underset{(17.80)}{-42.8448} - \underset{(0.17)}{0.3077} \ln P_{1t} \underset{(0.68)}{-0.2827} \ln(Q_{sub}) + \underset{(1.71)}{4.8360} \ln(pop) \qquad R^2 = .33$$

[a] Estimated standard errors in parentheses.

$$(8) \qquad X_1 = (27{,}065.225)\, P_1^{-.31},$$

$$(9) \qquad X_2 = (7{,}769.357)\, P_2^{-.05}.$$

Production Possibilities Frontier

Given the joint nature of the production of soybean oil and protein, the most appropriate mathematical specification of the production possibilities frontier is that of a cone (Fare and Jansson):

$$(10) \quad F = \{(X_2 - \delta_0 X_1)^{\delta_3} + \delta_1 (X_1 - \delta_2 X_2)^{\delta_3}\}^{1/\delta_3} - K_0 = 0,$$

for $\delta_0 \leq X_2/X_1 \leq 1/\delta_2$, and F being unspecified otherwise.

This equation represents a family of functions of which equation (1) of the economic model is a member (with $\delta_0 = \delta_2 = 0$); δ_3 is the parameter of elasticity corresponding to ϕ_0 of equation (1); and δ_0 and δ_2 establish rays which emanate from the origin to restrict the range of transformation. Given an estimate of δ_3 plus observed quantities of oil and protein, ϕ_1 may be derived from equation (2) if both δ_0 and δ_2 are zero. Insertion of ϕ_0 and ϕ_1 in equation (1) provides a solution of K_0, thereby completing the set of parameters required for solution of the model.

If it is assumed that component pricing of soybeans has not taken place in the past, predictions of the values of $\delta_0, \ldots, \delta_3$ may not be based upon observed annual production of soybean oil and protein. With no change in the relative prices of protein to oil paid to producers, any fluctuation in the average oil/protein content of American soybeans should be random. To obtain data which can identify the range of production possibilities available to producers once component pricing is introduced, observations have been drawn from the recorded results of breeding efforts conducted by agronomists at experiment station sites (Uniform Soybean Tests, 1972–76). The quantities of oil/acre and protein/acre for twenty seed varieties grown at seventy locations have been calculated (Updaw).

The agronomists who have recorded the results of these experiments have not consistently reported the quantities of inputs employed each year. Those factors of production which have been found to influence the chemical composition of soybeans include nitrogen (Ham et al.), lime, phosphorus and potassium (Lutz and Jones), and seed variety (Nichols, Clapp, Perrin). Without observations of factor

use, calculated observations of oil per acre and protein per acre are not amenable to the direct estimation of a production possibilities frontier; however, variation in component production may be attributed to the effects of locational differences, differences among years, and variety effects, if these are independently distributed. By identifying that variation attributable to changes in variety, a production frontier may be estimated. This may be achieved through an analysis of variance in which production of each component is determined by location, year, and variety:

$$(11)\quad X_{1ijk} = \mu_1 + V_{1i} + L_{1j} + R_{1k} + \epsilon_{1ijk},$$

$$(12)\quad X_{2ijk} = \mu_2 + V_{2i} + L_{2j} + R_{2k} + \epsilon_{2ijk},$$

where X_{1ijk} is observed production of protein per acre of variety i at location j during year k, in pounds; X_{2ijk}, observed production of oil per acre of variety i at location j during year k, in pounds; V_{1i}, fixed varietal effect on protein per acre of variety i; V_{2i}, fixed varietal effect on oil per acre of variety i; L_{1j}, fixed location effect on protein per acre for location j; L_{2j}, fixed location effect on oil per acre for location j; R_{1k}, fixed year effect on protein per acre for year k; R_{2k}, fixed year effect on oil per acre for year k; ϵ_{1ijk}, random protein effect for variety i, location j, year k; and ϵ_{2ijk}, random oil effect for variety i, location j, year k.

The estimated variety effects provide the basis for the data required for the production possibilities frontier:

$$(13)\quad X'_{1i} = \mu_1 + V_{1i},$$

$$(14)\quad X'_{2i} = \mu_2 + V_{2i},$$

where X'_{1i} is estimated protein production for variety i, and X'_{2i} is estimated oil production for variety i.

With the members of the sample determined, all that remains is to estimate the elasticity coefficient of the production possibilities frontier. This is achieved through the use of nonlinear regression (Gallant, Schmidt). While the small sample properties of this procedure remain undocumented, it is known that the estimators are asymptotically unbiased, efficient, and consistent (Gallant). With 635 observations in the sample, it will be assumed that the estimators possess the asymptotic properties.

The results of the nonlinear regression are presented in table 3. The point estimate of the parameter of transformation, δ_3, is so close to unity that the elasticity of transformation approximates infinity. Furthermore, the slope of the function is positive throughout the transformation range. This implies that the economically relevant frontier consists of a single point. Therefore, the effective value of the elasticity of transformation is zero. If this conclusion is correct, the national production of oil and protein could not have been expected to change had the component pricing of soybeans been in effect.

Table 3. Nonlinear Least Squares Regression of Production Possibilities Frontier

Source	*df*	Sum of Squares	Mean Square
Regression	5	−228880516.287	−45776103.257
Residual	630	228880516.287	363302.407
Total	635	0	

Parameter	Estimate	Asymptotic Standard Error of Estimate
δ_0	0.3588	1.1673
δ_1	0.3923	0.6906
δ_2	1.6493	5.0501
δ_3	1.0277	1.0738
K_0	410.7642	380.1349

Social Costs and Benefits

With no expected change in the chemical composition of soybeans, there can be no social benefits for consumers of soybean oil and protein from the introduction of component pricing. With no change in the supply of these goods, equilibrium quantities and prices for consumers remain constant. The only effect would be to force the ratio of producer prices to equal that for consumers, thereby redistributing income among producers without changing total revenue. With no change in consumers' surplus or producers' surplus, gross benefits are predicted to be zero.

Niernberger's estimates of ownership and operating costs of NIR instruments provide a basis upon which to determine the social cost of component pricing. Measurement cost is calculated as a weighted average of these estimates, where the weights represent the fraction of American processing mills which have annual operating capacity in the ranges outlined by Niernberger. In the construction of weighted-average screening cost, it is assumed that Niernberger's high estimates apply and that all mills with estimated annual operating capacity exceeding 5.0 million bushels will incur a measurement cost of 0.5¢ per bushel

processed (Updaw). On this basis, the social cost of component pricing is estimated to be 0.81¢ per bushel processed per year if components are measured only once before processing.

It is not likely that soybean components would be measured only at the market where the processor purchases soybeans. Traders at country points or subterminal elevators should be unwilling to bear the risk of being assessed the relatively large discounts that would be associated with component pricing (Updaw, Bullock, Nichols). Components might be measured two or three times, on the average, before soybeans are crushed. Therefore, it is assumed that component measurement would occur 2.5 times as soybeans progress through domestic marketing channels. For the average year during 1971–75, this would imply an annual social cost of $12,585,375.

With estimated social benefits of zero, the study indicates that the component pricing of soybeans would have reduced social welfare in the United States over the period 1971–75 by $12,585,375 per year.

Sensitivity Analysis

The estimated social costs and benefits of component pricing are derived from the estimated parameters of the domestic demand for soybean oil, the domestic demand for soybean protein, and the production possibilities frontier. Because the values of these parameters are never known with certainty, it may be worthwhile to recompute social costs and benefits using different values of the parameters of the economic model.

As a first step, assume that the production possibilities frontier possesses some range of transformation. Nichols, Clapp, and Perrin determined an approximately linear trade-off between the oil content and protein content of different soybean varieties that is 1:1. This is not inconsistent with the nonlinear regression results of this study, since the estimated frontier of this study includes the effect of differences among varieties in yield. However, let us impose an elasticity of transformation of -1.0 and $-\infty$ on the model, ensuring that the marginal rate of transformation is -1.0 at the average value of oil and protein production over 1971–75. The results are presented in the second and third rows of table 4.

In each case, the predicted equilibrium output of oil/protein lies within the rays of the estimated cone of table 3. In the iteration in which the elasticity of transformation equals -1.0, predicted oil production for the average year during 1971–75 increases by 49.08 million pounds and predicted protein production decreases by 49.36 million pounds, compared to the quantities actually observed. This corresponds to an estimated decline in the real consumer price of oil of 2.53¢ per pound and an

Table 4. Results of Sensitivity Analysis

	Predicted Change in:					
Model Assumptions	Oil Production	Protein Production	Oil Surplus	Protein Surplus	Producer Surplus	Net Social Welfare
	--(million pounds)--		($ million)			
$\lambda = 0$[a] $\gamma_1 = -.05$ $\epsilon_1 = -.31$	0	0	0	0	0	−12.6
$\lambda = -1.0$ $\gamma_1 = -.05$ $\epsilon_1 = -.31$	49.08	−49.36	170.43	−25.31	−144.41	−11.9
$\lambda = -\infty$ $\gamma_1 = -.05$ $\epsilon_1 = -.31$	52.87	−52.87	182.31	−27.26	−154.30	−11.9
$\lambda = -1.0$ $\gamma_1 = -.5$ $\epsilon_1 = -.31$	171.44*[b]	−174.96*	62.54	−91.51	31.99	−9.6
$\lambda = -\infty$ $\gamma_1 = -.5$ $\epsilon_1 = -.31$	172.64*	−172.64*	62.71	−89.85	30.73	−9.0

[a] λ is elasticity of transformation; all other variables are as defined earlier.
[b] Asterisk denotes a corner solution.

estimated increase in the real consumer price of protein of 0.22¢ per pound. Calculated changes in consumers' surplus and producers' surplus sum to $708,000, far less than the cost of measuring soybean components.

With the elasticity of transformation made infinitely elastic, the quantity response is greater, as would be expected. A predicted increase in the annual production of oil by 52.87 million pounds leads to a predicted decrease in the annual production of protein by 52.87 million pounds. Equilibrium prices for consumers are estimated to fall by 2.71¢ per pound for oil and rise by 0.24¢ per pound for protein. Estimated gross social benefits become $756,000 per year, which is exceeded by measurement costs. Again, it is predicted that the component pricing of soybeans would have reduced social welfare over the period 1971–75. Even if soybean producers face perfectly elastic transformation frontiers, the model predicts that the increased consumer surplus in the oil market would not have been large enough to compensate protein consumers and soybean producers as well as cover the cost of screening.

An additional parameter of the model to be changed might be the elasticity of demand for soybean oil (γ_1). The estimate reported in this study is much less elastic than those published in recent years; therefore, it might be suspect. To determine the effect of this parameter on the results of the study, the elasticity of demand for oil has been changed to $-.5$ and solutions to the model have been obtained for an elasticity of transformation of -1.0 and $-\infty$. The results are presented in the fourth and fifth rows of table 4.

In each of these iterations, the equilibrium solution lay beyond the range of transformation outlined by the rays of the predicted frontier. Therefore, the solution obtained was located at the corner of a ray and the transformation surface. In these cases, the predicted price ratio for consumers does not equal that for the producing sector; however, the divergence between the two is less than that which existed without component pricing. The corner solution represents an equilibrium in which oil production is lower and protein production higher than that which would be predicted for an unconstrained case.

Two effects of increasing the elasticity of demand for soybean oil are to raise predicted annual oil production and to lower the predicted gain in consumers' surplus for oil consumers. These, in turn, lead to predicted increases in producers' surplus and a decline in total consumer welfare. In both cases, the gain in welfare for soybean producers and oil consumers is not great enough to compensate the loss of consumers' surplus in the protein market and to cover the social cost of screening soybeans. In these cases, as well as the others, the predicted net effect of the component pricing of soybeans over the period 1971–75 would be to reduce social welfare in the United States.

Summary

The purpose of this study has been to predict the social costs and benefits of the component pricing of soybeans in the United States. A model consisting of the demand for soybean oil and soybean protein and a production possibilities frontier was developed so that changes in equilibrium quantities and prices might be estimated. The salient parameters of the model were estimated for the average year during the period 1971–75, so that conclusions might be drawn from predictions based upon recent experience.

The result of the empirical work was that there would have been no change in the quantities of oil and protein produced and consumed in the United States had soybeans been priced in accordance with component value. Because component pricing can be achieved only at some additional cost, it was concluded that component pricing would have reduced social welfare over 1971–75.

Next, certain parameters of the model were changed and social benefits recomputed to assess the sensitivity of the conclusion to different parameter values. In every case examined, the expected social cost of the component pricing of soybeans exceeded its predicted social benefits. While changes in producers' and consumers' surplus were predicted to be sizeable, the gain to one group tended to be nearly completely offset by losses to others.

In comparison with the annual expenditure on soybean oil and protein in the United States, predicted marginal social costs and benefits are extremely small. For example, if the net social cost of component pricing had been $12,585,375 per year and had this cost been borne proportionally by consumers of oil and protein, the average real price of each good over 1971–75 would have risen by less than .075¢ per pound. Nevertheless, the sensitivity

analysis indicates that net social benefits were not likely to be positive, even if the elasticity of product transformation is perfectly elastic. On the basis of these results, it appears that the component pricing of soybeans should not raise social welfare if implemented in the near future.

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References

Fare, R., and L. Jansson. "Joint Inputs and the Law of Diminishing Returns." *Zeitschrift für Nationalekonomie* 36(1975):407–36.

Gallant, A. R. "Nonlinear Regression." *Amer. Statistician* 29(1975):73–81.

Graf, T. *Do Protein Testing and Premium Payments Have a Place in the Dairy Picture?* Dep. Agr. Econ. Staff Pap. Ser. No. 65, University of Wisconsin, 1973.

Ham, G. E., et al. "Yield Composition of Soybean Seed as Affected by N and S Fertilization." *Agronomy J.* 67(1975):293–97.

Heady, E. *Economics of Agricultural Production and Resource Use.* Englewood Cliffs, N.J.: Prentice-Hall, 1952.

Houck, J. P., and J. S. Mann. *Domestic and Foreign Demand for U.S. Soybeans and Soybean Products.* University of Minnesota Agr. Exp. Sta. Tech. Bull. No. 256, 1968.

Houck, J. P., M. Ryan, and A. Subotnik. *Soybeans and Their Products: Markets, Models and Policy.* Minneapolis: University of Minnesota Press, 1972.

Kihlstrom, R. E. "Firm Demand for Information about Prices and Technology." *J. Polit. Econ.* 84(1976):1335–41.

Kmenta, J. *Elements of Econometrics.* New York: Macmillan Co., 1971.

Ladd, G. W., and M. B. Martin. "Prices and Demands for Input Characteristics." *Amer. J. Agr. Econ.* 58(1976):21–30.

Lutz, J. A., Jr., and G. D. Jones. "Effect of Irrigation, Lime and Fertility Treatments on the Yield and Composition of Soybeans." *Agronomy J.* 67(1975):523–26.

Nichols, T. E., Jr., J. G. Clapp, and R. K. Perrin. *An Economic Analysis of Factors Affecting Oil and Protein Content of Soybeans.* Dep. Econ. and Bus. Econ. Info. Rep. No. 42, North Carolina State University, 1975.

Nicholson, W. *Microeconomic Theory: Basic Principles and Extension.* New York: Holt, Rinehart, & Winston, 1978.

Niernberger, F. F. *Near-Infrared Reflectance Instrument Analysis of Grain Constituents: A Cost Study.* Washington, D.C.: USDA ESCS-20, 1978.

Perrin, R. K. "The Impact of Component Pricing of Soybeans and Milk." *Amer. J. Agr. Econ.* 62(1980):445–55.

Rinne, R. W., et al. *Soybean Protein and Oil Percentages Determined by Infrared Analysis.* Washington, D.C.: USDA ARS-NC-26, 1975.

Schmidt, P. "On the Statistical Estimates of Parametric Frontier Production Functions." *Rev. Econ. and Statist.* 18(1976):238–39.

U.S. Department of Agriculture. *Agricultural Statistics* Washington, D.C., 1947–77.

———. *Uniform Soybean Tests.* Washington, D.C.: Agr. Res. Serv., 1972–1976.

Updaw, N. J. "Market Analysis of the Component Pricing of Soybeans." Ph.D. thesis, North Carolina State University, 1979.

Updaw, N. J., J. B. Bullock, and T. E. Nichols, Jr. "Pricing Soybeans on the Basis of Oil and Protein Content." *S. J. Agr. Econ.* 8(1976):129–32.

Vandenborre, R. "Demand Analysis of the Markets for Soybean Oil and Soybean Meal." *J. Farm Econ.* 48(1966):924–34.

Multiple Exchange Rate Changes and U.S. Agricultural Commodity Prices

Keith J. Collins, William H. Meyers, and Maury E. Bredahl

A model was developed to assess recent effects of exchange rate changes, inflation, and price insulation policies on real U.S. commodity prices. Exchange rate effects are defined so that they can occur and be significant under either fixed or floating rate regimes. The results indicate exchange rate effects on real U.S. commodity prices are smallest under free trade and real commodity price insulation policies but rise substantially as nominal price insulation policies become more prevalent.

Key words: exchange rates, inflation, price insulation policies.

The coincidence of the depreciation of the dollar against many foreign currencies with the rapid expansion of U.S. agricultural exports in the seventies has suggested to some economists that a strong relationship exists between exchange rates and agricultural trade (Schuh). By implication, a relationship is hypothesized between the domestic prices of agricultural commodities and the relative value of the dollar. Empirical results, although subject to valid criticism of specification and theoretical constructs, have provided support for an exchange rate effect but have differed with respect to its magnitude (Fletcher, Just, Schmitz; Chambers and Just; Johnson, Grennes, Thursby; Yandle). Our purpose is to assess the size and nature of such a relationship by developing a framework for examining the effects of recent changes in the value of the dollar.

A change in purchasing power is the ultimate source of a trade response to changes in the value of the dollar. In the early 1900s Cassel originated the purchasing power parity (PPP) theorm, which holds that a bilateral exchange rate reflects the relative domestic purchasing power of the currencies. While not without criticism, PPP has been accepted in empirical work to mean that changes in bilateral floating exchange rates are a function of divergent rates of inflation. The PPP hypothesis suggests that real trade flows may be induced if movements in the exchange rate and relative inflation rates diverge. This situation can occur under either floating or fixed exchange rate regimes. Suppose a country experiences an internal rate of inflation which exceeds that of potential import suppliers. If the exchange rate is fixed, the import prices (reflecting inflation in other countries) do not increase as rapidly as domestically produced import substitutes. The divergent rates of inflation, given a fixed exchange rate, should induce an expansion of the country's imports. This situation, of course, cannot continue indefinitely because foreign exchange shortages resulting from balance-of-trade deficits ultimately will force a devaluation of that currency. If the adjustments in an exchange rate simply reflect divergent rates of inflation, little response in trade flows would be expected.

The above logic argues that exchange rate effects can occur in the absence of exchange rate changes. Thus an understanding of the relationship between exchange rates and commodity prices should profit from an analysis which incorporates relative rates of inflation and exchange rate changes. With commodity producers and consumers having to adapt their behavior to the global inflation of the seventies, some recent empirical trade studies (Bale and Greenshields; Johnson, Grennes, Thursby; Konandreas, Bushnell, Green) have benefited from the use of general price level variables. This analysis is con-

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cerned with exchange rate effects that include relative inflation rates as an intrinsic part of an exchange rate effect.

Exchange rate analyses relying on theoretical models limited to free trade or two countries are misleading. Although studies such as those of Abbott and Hillman have recognized barriers to free trade, measurement of the extent to which trade barriers constrain or enhance exchange rate impacts has received little attention. In addition, the dollar has depreciated against the currencies of many developed countries while appreciating against those of many less developed countries. The developed countries primarily import soybeans and corn, while the less developed countries import more wheat and cotton. Hence, one would not expect a single measure (such as the SDR) to serve very well for all commodities. An analytical model that considers multilateral exchange rate changes is essential.

The impact of multilateral exchange rate changes on U.S. prices of major agricultural commodities is analyzed by developing a simple analytical method which incorporates multiple exchange rate changes, rates of inflation, and trade restrictions. The first section of the paper presents the theoretical foundation for the analysis by developing an expression for short-run U.S. commodity price changes caused by both nominal exchange rate changes and exchange rate changes adjusted for differential inflation rates. The second section presents calculated annual changes in U.S. prices of wheat, corn, soybeans, and cotton attributed to exchange rate changes and inflation rates of major noncommunist nations during the period 1971 to 1977. These changes are compared with the observed changes in prices in order to determine where, in the range from small to large, exchange rate impacts on U.S. agriculture may be placed.

Analytical Method

The theoretical approach is developed by specifying a world market equilibrium system for each commodity. Such a system consists of (*a*) a domestic demand and (*b*) a supply relation for each country engaged in trade, (*c*) a market clearing world equilibrium condition, (*d*) currency linkages based on a numeraire currency, and (*e*) price linkage equations based on a numeraire country. This system is totally differentiated, yielding an expression for the percent change in the numeraire price that is associated with multiple exchange rate changes (Ridler and Yandle; Bredahl, Meyers, Collins). The United States is used as the numeraire country in the study with the U.S. dollar as the numeraire currency.

Model

Consider the following simple spatial model for a particular commodity. We abstract only partially from demand and supply shifters and express a country's domestic demand, D_i, as a function of own price, P_i, and an alternative price, OP_i, which represents all other items or the general level of output prices (a deflator). Domestic supply, S_i, depends on the lagged values of own price and the same alternative price. The alternative price represents substitutes in both demand and supply. All prices are defined in the domestic currency of each country. We assume that demand and supply are homogenous of degree zero in prices. Demand and supply for the *i*th country may then be written as

(1) $D_i = D_i(P_i/OP_i) = D_i(RP_i)$, and

(2) $S_i = S_i[(P_i/OP_i)_{-1}] = S_i[(RP_i)_{-1}]$,

where RP_i indicates real price and the subscript, minus one, a one-year lag. An increase in the price term would be expected to reduce current quantity demanded and increase quantity supplied in the following year. In this formulation, the alternative price is exogenous to the model and unaffected by exchange rate changes, implying a price heavily weighted by nontraded goods. Further, a change in the exchange rate of the country is assumed to have no effect on the real income term in the demand equation; hence, it is not included in equation (1).

The analysis is partial equilibrium. Our interest is in each country's demand and supply curves in the real price/quantity plane. Inflation and exchange rate changes are restricted to movements along a curve. We will explain changes in U.S. commodity prices due to monetary variables (exchange rates and inflation), rather than to curve shifters such as real income, weather, and others. This means working on the demand side with a compensated demand curve. The percent change in U.S. prices explained by exchange rates and inflation will, as a result, be a partial effect. The effects of other demand and supply factors would be required to explain the actual

commodity price movement, or total effect.

The world equilibrium condition simply states the sum of all demands equals the sum of all supplies. Denoting the demand and supply of the United States, D_{us} and S_{us}, this condition is expressed as U.S. export supply equals the demand for U.S. exports,

$$(3) \qquad S_{us} - D_{us} = \Sigma_i(D_i - S_i).$$

The summation operator here, and subsequently, excludes the United States. The nominal internal price in each country is linked to the numeraire price, P_{us}, by the relation

$$(4) \qquad P_i = g_i(e_iP_{us}),$$

where e_i is the value of the ith country's currency per U.S. dollar. The functional specification, g_i, represents the price transmission mechanism and implicitly subsumes direct factors such as transportation costs and less direct factors such as trade restrictions and price intervention policies.

Total differentials of equations (1)–(4) are

$$(5) \qquad dD_i = D'_idRP_i = D'_i[(OP_idP_i - P_idOP_i)/OP_i^2],$$

$$(6) \qquad dS_i = S'_id(RP_i)_{-1},$$

$$(7) \qquad dS_{us} - dD_{us} = \Sigma_i(dD_i - dS_i), \text{ and}$$

$$(8) \qquad dP_i = g'_i(e_idP_{us} + P_{us}de_i).$$

Equations (5), (6), and (8) may be substituted into equation (7) to yield

$$(9) \qquad \frac{dRP_{us}}{RP_{us}} = \left[\Sigma_iD_iN_i\frac{dZ_i}{Z_i} - {}_iS_iE_i\left[\left(\frac{dZ_i}{Z_i}\right)_{-1} + EP_i\left(\frac{dRP_{us}}{RP_{us}}\right)_{-1}\right] - S_{us}E_{us}\left(\frac{dRP_{us}}{RP_{us}}\right)_{-1}\right]\Big/ - (D_{us}N_{us} + \Sigma_iD_iN_iEP_i),$$

where

$$(10) \qquad \frac{dZ_i}{Z_i} = EP_i\frac{de_i}{e_i} + EP_i\frac{dOP_{us}}{OP_{us}} - \frac{dOP_i}{OP_i},$$

$$(11) \qquad EP_i = g'_i\frac{e_iP_{us}}{P_i}.$$

In equation (9), N_i and E_i are elasticities of domestic demand and supply in the ith region with respect to real domestic price. EP_i is the elasticity of nominal price transmission. When $EP_i = 1$, equation (10) defines an inflation-adjusted (or purchasing power parity) exchange rate change.

Equations (9) and (10) reveal the economic forces at work. The percent change in the current real U.S. commodity price depends on (a) the changes in general price levels and exchange rates in the current period and (b) the supply effect due to price and exchange rate changes in the previous period.

Demand and Supply Effects

The current period changes in exchange rates and alternative prices operate through the demand side only. This demand effect is measured by the first term of equation (9). For a nonzero EP_i, an increase in the bilateral exchange rate (appreciation of the dollar) or in the U.S. general price level reduces the current real U.S. commodity price.

The demand effect of alternative prices in other countries reflects the substitution with other commodities. An increase (decrease) in foreign general price levels increases (reduces) foreign demand and current U.S. price.

The supply side, by assumption, is affected only by the lagged values of prices and exchange rates. The lagged effects of all previous exchange rate and alternative price changes are captured by the two supply terms of equation (9). The first supply term measures the foreign supply effect. The second supply term measures the U.S. supply effect.

The bracketed expression in the first supply term is the percent change in the lagged real domestic price in the ith country. This lagged real price change determines current period supply. For a nonzero EP_i, an increase in the lagged bilateral exchange rate or in the lagged nominal U.S. commodity price (due to past inflation and exchange rate changes) tends to increase foreign supply, reducing current real U.S. commodity price. An increase in lagged foreign alternative prices tends to decrease the foreign supply effect, increasing current U.S. commodity price. (Note that from the foreign supply viewpoint, the effects of changes in alternative U.S. prices net to zero.)

An increase in lagged real U.S. commodity price will increase current U.S. supply and tend to reduce current price. If the level of U.S. supply is large relative to total world demand, the U.S. supply term will tend to

dominate the expression for the total supply effect.

Inflation and Exchange Rate Effects

Although we are interested primarily in combined, or inflation-adjusted exchange rate effects, the separate effects of inflation and bilateral exchange rate changes can be determined. To determine the impact of inflation, independent of exchange rate effects, all exchange rate changes are set equal to zero, and the time path of real price changes, due to general price level changes, is calculated. Alternatively, setting all price changes equal to zero and tracing exchange rate changes determines the real price effects due to exchange rates independent of other price changes.

Price Insulation Policies

The linkage of internal and world market prices is an essential factor in determining the impacts of exchange rates on U.S. commodity prices. We consider a free trade policy and two types of price insulation policies.

Free Trade. We use free trade policy to describe the situation where the nominal price transmission elasticity is near one. For simplicity we assume the nominal price transmission is perfect, $EP_i = 1$, under free trade. Equation (10) then gives

$$(12) \quad \frac{dZ_i}{Z_i} = \frac{de_i}{e_i} + \frac{dOP_{us}}{OP_{us}} - \frac{dOP_i}{OP_i}.$$

The change in current U.S. price depends on the change in the bilateral exchange rate relative to the divergent rates of inflation. If exchange rate changes reflect PPP theory, the sum of these terms will be zero.[1] In this case, there would be no current price effects, hence, no subsequent supply effects in later periods. Exchange rate effects would emanate only from movements of disequilibrium rates to equilibrium and from equilibrium rates to disequilibrium.

Nominal Price Insulation Policies. If the EP_i is less than one, exchange rate changes that reflect PPP theory would result in a divergence between changes in real commodity prices in the United States and those in foreign countries. Trade and price effects in the United States would be created. The closer EP_i is to zero, or to perfect domestic nominal price insulation, the more dominant the foreign inflation rate becomes in determining supply and demand changes.

The perfect insulation of domestic nominal prices reduces the price linkage equation (10) to a single term,

$$(13) \quad \frac{dZ_i}{Z_i} = -\frac{dOP_i}{OP_i}.$$

Thus, current foreign demand is influenced only by the current change in other prices. Similarly, foreign supply is influenced only by the lagged value of other prices. Foreign demand would be increased by foreign inflation tending to increase U.S. commodity prices. Supply would be decreased by inflation, also tending to increase U.S. prices.

A nominal price insulation policy, with inflation, would result in a declining real consumer and producer price of a commodity. Such a situation has been noted for the real Japanese consumer price of wheat over relatively long periods (Gallagher, Lancaster, Bredahl). Nominal price insulation also may be descriptive of cotton prices in many less developed countries.

Real Price Insulation Policies. If consumption levels and/or farm income parity are policy goals, rather than nominal prices, the nominal price transmission specified in equation (4) may not obtain. Real price may be the policy target. Nominal prices would be adjusted to mitigate the effects of domestic inflation. For this case, the model is modified to reflect a real price insulation specification.[2] Equation (9) remains the same, but equation (10) becomes

$$(14) \quad \frac{dZ_i}{Z_i} = EP^*_i \left(\frac{de_i}{e_i} + \frac{dOP_{us}}{OP_{us}} - \frac{dOP_i}{OP_i}\right).$$

For a country with perfect domestic real price insulation, $EP^*_i = 0$, intertemporal demand and supply changes would be zero.

In this case, divergence of the exchange rate from that suggested by the PPP theory will not induce demand or supply changes. One would suspect that this type of price insulation policy most likely would be followed in countries with high rates of inflation.

[1] See Officer for a review of PPP. He labels this short-run interpretation of PPP an extreme view.

[2] This may be derived using equations (1)–(3), and $RP_i = h_i(R_iRP_{us})$, where the inflation-adjusted exchange rate, R_i, is defined as $R_i = e_i \dfrac{OP_{us}}{OP_i}$. Defining EP^*_i as the real price transmission elasticity, $dZ_i/Z_i = (EP^*_i)\, dR_i/R_i$.

The existence of price insulation policies has a potentially significant impact on the effect of bilateral exchange rate changes and rates of inflation. The nominal price insulation case acts as an upper bound on the price effects under restricted trade, because of the demand and supply changes caused by foreign inflation. The real price insulation case represents a lower bound under restricted trade, as governments attempt to insulate real domestic market forces.

Data and Assumptions

Historical values of exchange rates and general prices are used to compute both their combined (inflation-adjusted exchange rate) effects and separate, or decomposed, effects on U.S. commodity prices. The analysis is replicated under free trade and restricted trade assumptions, using both nominal and real price insulation alternatives. Both current demand and lagged supply effects are isolated.

The necessary data include (*a*) demand and supply elasticities, quantities demanded and supplied, and inflation rates for all countries; (*b*) percent changes in foreign currency values of the U.S. dollar; and (*c*) elasticities of price transmission for all countries. The requirements are large but not restrictive. Trade data and exchange rates are widely reported. Numerous estimates of demand and supply elasticities are available for many countries. Trade policies are well-documented providing information for determining the price transmission elasticities.

Thirty-seven foreign countries were selected to provide breadth in coverage of total consumption, production, and trade in market economies for the four commodities of interest. Central plan countries were excluded from consideration due to the inability to obtain appropriate data and acceptance of the hypothesis that price movements along internal demand and supply curves have not been principal inducements to agricultural trade.[3] Of the market economies during 1970 to 1977, the countries used in the calculations accounted for 70% of wheat, 77% of corn, 95% of soybean, and 85% of cotton consumption. Their shares in production were 83% for wheat, 75% for corn, 96% for soybeans, and 81% for cotton.

[3] This is equivalent to the real-price transmission case with $EP^*_i = 0$ for central plan countries.

For consistency across commodities, changes in exchange rates and general price levels are computed for a compromise September/August crop year. The exchange rate series selected as most appropriate is a period-average trade conversion rate, the International Monetary Fund's (IMF) "rf" series.

There are many possibilities for the alternative price, or deflator, used in the internal demand and supply equations. Any broad-based measure of general price levels that has a small imported good component (candidates are the GNP deflator, consumer or producer price indexes, index of unit labor costs, etc.) is reasonable, since changes in exchange rates are assumed to have little or no impact on the deflator. The producer price index (PPI) is used here because the agricultural product supply is a primary commodity supply and the demand is a derived demand. The PPI may better reflect available substitution opportunities in supply and demand because decision variables would include prices of inputs, other primary commodities, or semimanufactured and manufactured products not yet at the final production state.

For a given commodity, the same internal short-run domestic demand and supply elasticities are used for each country. The demand and supply elasticities (identical to those used in previous analyses by Johnson, and Bredahl, Meyers, Collins) are −.2 and .2 for wheat and cotton and −.4 and .2 for corn and soybeans.

Procedures and Results

Results of the analysis are reported in three sections. First, we compare the impacts of exchange rate changes in a world characterized by free trade, nominal-price insulation policies, and real-price insulation policies. Second, the computed change in real wheat price is decomposed into demand, supply, exchange rate, and inflation effects. Finally, the time path of actual real-price changes of the major commodities for the 1971/72 to 1977/78 crop years are compared with the computed results.

Under free trade, price transmission is perfect; thus, the differences in results due to nominal and real price insulation can arise in the restricted cases only. The nominal-price insulation case assumes that price-insulating countries do not adjust commodity prices in

response to internal inflation. The real-price insulation case assumes commodity prices in insulating countries are pegged to general price levels as measured by the PPI.

In the restricted trade cases, the elasticity of price transmission is set equal to zero for countries that exhibited significant market insulation policies during part or all of the seventies, and it is set equal to 1 for the remaining countries. Although these polar cases are unlikely to hold rigorously over time for each country, their use obviates the selection of an intermediate point. The free trade case assumes the elasticity of price transmission is 1 for all countries. Consideration of the free trade and restricted trade cases permits flexibility; it provides a measure of the sensitivity of exchange rate effects to different levels of effectiveness of price insulation policies of major trading nations.

Supply effects of previous exchange rate changes in the initial period of analysis, 1970/71–1971/72, are assumed to be zero.[4] For subsequent periods, inflation-adjusted exchange rate effects are determined using the current period data and the previous period's computed exchange rate effect.

[4] Our interest is in the exchange and inflation rates of the 1970s, so we desire a base year (the year preceding the first year analyzed) that closely precedes the seventies. Inflation-adjusted exchange rate effects in the base year should be minimal so that little bias is introduced by assuming no lagged supply effects in the first year of analysis. To the extent that a real-price-increasing (decreasing) supply effect exists in the first year of analysis, the results understate (overstate) the exchange rate effects.

Impact of Price Insulation Policies

The impact of exchange rate changes and inflation on real U.S. commodity prices depends critically on the nature of the price insulation policies of foreign countries. In most cases, the magnitude of real price effects is least under real-price insulation prices, somewhat larger under free trade, and largest under nominal-price insulation policies (table 1).

Price insulating policies do not mitigate the impact of exchange rate changes and foreign inflation. Almost without exception, the impact is largest under nominal-price insulation policies. In a few comparisons, even the real-price insulation case results in larger changes than the free trade case.

It is not surprising that the results for the real linkage case are generally similar in sign and magnitude to the free trade case, since the real linkage case is, analytically, the free trade case applied to a smaller world. These results imply that if countries practicing price insulation attempted to hold real prices fixed during the seventies, the inflation-adjusted exchange rate impact on U.S. prices would not have been much different than if they had engaged in free trade.

Foreign inflation explains why the nominal linkage case shows much larger inflation-adjusted exchange rate impacts than under the real-price insulation case or free trade.[5] The

[5] Brazil, Argentina, and Chile have been omitted from the analysis for wheat, corn, and cotton. Argentina and Chile were omit-

Table 1. Computed Inflation-Adjusted Exchange Rate Effects on Real U.S. Commodity Prices under Free Trade and Real- and Nominal-Price Insulation Policies

Item	From / To	1970/71 / 1971/72	1971/72 / 1972/73	1972/73 / 1973/74	1973/74 / 1974/75	1974/75 / 1975/76	1975/76 / 1976/77	1976/77 / 1977/78
		(% change)						
Wheat								
Real price insulation		3.3	0.9	7.4	−4.8	−2.8	0.2	2.4
Free trade		1.9	0.4	8.3	−2.9	−4.0	0.8	2.1
Nominal price insulation		6.6	8.6	24.6	4.1	4.9	9.1	8.3
Corn								
Real price insulation		0.9	0.5	2.4	−1.8	0	0.4	0.8
Free trade		1.6	0.8	3.9	−1.3	−1.5	−0.7	1.6
Nominal price insulation		2.4	3.6	10.1	2.2	3.3	7.2	11.5
Soybeans								
Real price insulation		2.4	0.9	3.3	−2.7	−0.2	1.1	1.3
Free trade		2.4	0.9	3.1	−3.0	0.2	2.1	1.0
Nominal price insulation		5.0	3.6	6.9	−1.5	5.1	8.1	6.8
Cotton								
Real price insulation		3.0	0.4	0.3	−1.7	−3.8	−2.1	−0.3
Free trade		0.4	−2.6	7.3	−4.1	−0.3	−0.5	4.8
Nominal price insulation		6.6	10.3	22.2	7.5	4.8	6.7	11.3

Note: The nominal-price insulation case assumes trade-restricting countries fix domestic nominal commodity prices. The real-price insulation case assumes nominal commodity prices are insulated from world market prices but pegged to a general price level.

principal reasons for this disparity would be the demand-increasing effects of rising prices of substitutes and supply-reducing effects of increased foreign production costs.

A similarity of the results for wheat and cotton, under all cases, should be noted. A similar correspondence exists for corn and soybeans. These results reflect the importance (supply and demand weights) of major producing and consuming countries. The results for corn and soybeans are dominated by developed countries (European Community and Japan). These countries have experienced moderate rates of inflation; thus, smaller commodity price changes were computed under the nominal-price insulation case. The results for the free trade and real-price insulation cases indicate exchange rate changes have almost completely compensated for divergent rates of inflation.

Wheat and cotton are produced and consumed primarily in less developed countries (LDCs). Characteristically, these countries have experienced large rates of inflation which account for the relatively large impacts under the nominal-price insulation case. However, if these countries attempted to adjust agricultural commodity prices to the domestic rate of inflation, the impact of inflation-adjusted exchange rate changes on U.S. commodity prices would be much smaller. These results underlie the need to take account of domestic price policies and inflation rates in empirical trade research.

ted for soybeans. The principal result of including these countries is larger inflation-adjusted exchange rate effects under nominal linkage, from 1974/75 on. This is due to their extremely large domestic inflation rates.

Decomposing Wheat Price Effects

In order to illustrate the factors contributing to the computed inflation-adjusted exchange rate effects, the restricted-trade wheat results are broken into separate exchange rate, inflation, demand, and supply effects (table 2).[6] Wheat policies are checkered with restrictions that result in numerous trade barriers. Barriers vary from the fixed import price of the European Community to the fixed Japanese consumer price; therefore, free trade is not descriptive of the effect of global wheat policies.

The separate exchange rate effects are, by derivation, identical under the two price insulation policies. We conclude that the magnitude of exchange rate impacts in the seventies depends decisively on whether an exchange rate impact is defined as that which was caused by changes in exchange rates alone or that which was caused by inflation-adjusted exchange rates. The computed change in real U.S. wheat price due to exchange rates alone is negative in five of seven years. This reflects the currency depreciations against the dollar of a number of wheat importers. Many countries, primarily LDCs, have pegged their currencies to the dollar.

[6] Decompositions of price effects for free trade and for the other commodities and the policy assumptions used are available from the authors on request.

Table 2. Decomposition of Inflation-Adjusted Exchange Rate Effects on Real U.S. Wheat Prices under Restricted Trade

Item[a] From / To	1970/71 – 1971/72	1971/72 – 1972/73	1972/73 – 1973/74	1973/74 – 1974/75	1974/75 – 1975/76	1975/76 – 1976/77	1976/77 – 1977/78
	(% change)						
Real price insulation							
Inflation-adjusted	3.3	0.9	7.4	−4.8	−2.8	0.2	2.4
Demand	3.3	1.5	6.3	−1.6	−6.7	2.4	1.0
Supply, foreign[b]	0	−1.3	1.7	1.0	1.2	−3.9	1.4
U.S.	0	−1.9	−0.5	−4.2	2.7	1.6	−0.1
Exchange rate	0.3	−0.1	−0.9	−0.5	−6.5	1.5	−7.1
Inflation	3.0	1.0	8.3	−4.3	3.7	−1.4	9.4
Nominal price insulation							
Inflation-adjusted	6.6	8.6	24.6	4.1	4.9	9.1	8.3
Demand	6.6	9.7	24.8	10.5	0.9	13.8	7.0
Supply, foreign	0	2.6	4.6	7.5	6.3	−2.0	6.4
U.S.	0	−3.7	−4.8	−13.9	−2.3	−2.7	−5.1
Exchange rate	0.3	−0.1	−0.9	−0.5	−6.5	1.5	−7.1
Inflation	6.3	8.7	25.5	4.6	11.3	7.6	15.3

[a] The nominal-price insulation case assumes trade-restricting countries fix domestic nominal commodity prices. The real-price insulation case assumes nominal commodity prices are insulated from world market prices but pegged to a general price level.
[b] The total supply effect is the sum of the foreign and U.S. supply effects.

Computed inflation effects account for the differences in the restricted trade results for wheat. In the real-price insulation case, the maximum increase in real wheat price due to inflation alone is 9.4%, for nominal price insulation the maximum jumps to 25.5%. Under real price insulation, downward commodity price pressure is indicated after 1973/74. Inflation effects under nominal price insulation, however, imply upward pressure on wheat prices throughout the entire period.

The decomposition of the restricted-trade, real-commodity price effects into their demand and supply contributions permits further insights. We conclude that exchange rate impacts during the 1970s depended on both current and past exchange rate changes and that the economic impact of these changes in any one year have often been offsetting. A current period U.S. dollar depreciation, coupled with foreign inflation, increases U.S. export demand inducing U.S. commodity price increases. This feeds into the next year as a supply-increasing incentive which puts downward pressure on U.S. prices in that period. The effect on wheat price from U.S. supply changes due to inflation-adjusted exchange rate changes was primarily negative, while the foreign supply effect was positive, offsetting the U.S. effect in almost every year.[7]

Offsetting demand and supply factors explain part of the small, separate exchange rate effect for wheat. For example, during 1972/73, the dollar depreciated about 10% against major Western Europe currencies and the yen. Decomposing the computed separate exchange rate effect of these depreciations into demand and supply effects for wheat reveals that the developed countries' demand effect on U.S. wheat price was about 4%. Offsetting supply effects and the demand effect of LDCs resulted in a net exchange rate effect of −0.1% (table 2). This is evidence of the inappropriateness of using simple exchange rate measures (often heavily weighted by developed countries) to infer exchange rate impacts for individual commodities.

Comparison with Actual Price Changes

The approach used measures the impact of inflation-adjusted exchange rates in isolation of other factors. This approach facilitates disentangling the effects of the factors affecting exports, hence commodity prices, during the seventies. A comparison of actual changes in real U.S. commodity prices with the computed price changes indicates the importance of exchange rates and inflation relative to the changes related to other factors.

To make the comparison, the "best" de-

[7] The assumed cobweb supply response causes the U.S. supply effect to be opposite in sign to the previous period's real price effect. The sign of the foreign supply effect, and thus the total supply effect, may agree or disagree in sign with last period's price effect, depending on foreign inflation and exchange rate changes of the previous period. The magnitude of the total supply effect is, of course, a result of the assumed cobweb model. Alternative lag patterns could be used to distribute the supply effect over several periods.

Table 3. Comparison of the Computed Real Price Changes, under Selected Price-Insulation Policies, with Actual U.S. Commodity Price Changes

Item	From / To	1970/71 / 1971/72	1971/72 / 1972/73	1972/73 / 1973/74	1973/74 / 1974/75	1974/75 / 1975/76	1975/76 / 1976/77	1976/77 / 1977/78
		(% change)						
Wheat[a]								
Computed		3.3	0.9	7.4	−4.8	−2.8	0.2	2.4
Actual		−3.1	21.6	107.7	−11.2	−17.9	−28.8	−21.3
Corn[a]								
Computed		0.9	0.5	2.4	−1.8	0	0.4	0.8
Actual		−22.6	35.6	45.7	3.7	−20.8	−20.9	−12.7
Soybeans[b]								
Computed		2.4	0.9	3.1	−3.0	0.2	2.1	1.0
Actual		2.5	34.5	13.2	2.1	−30.8	32.9	−20.3
Cotton[c]								
Computed		6.6	10.3	22.2	7.5	4.8	6.7	11.3
Actual		23.8	9.0	49.7	−50.5	35.6	9.5	−29.2

Note: Actual prices are prices received by farmers for wheat, corn, and soybeans in 1970 dollars. For cotton, mill price is used because large portions of the crop were forward-contracted in some years.
[a] Results based on real-price insulation policies.
[b] Results based on free trade.
[c] Results based on nominal-price insulation policies.

scription of the price insulation policies for each commodity was selected. We judged real-price insulation policies for wheat and corn, free trade for soybeans, and nominal price insulation for cotton to be representative of most of the seventies.[8] The strength of the implications is, of course, conditioned on the reasonableness of these selections.

Comparing price effects under the selected policies with actual price changes suggests inflation-adjusted exchange rates had a minor role in the large increases in commodity prices of wheat, corn, and soybeans during the early 1970s (table 3). For example, the real U.S. price of wheat increased almost 108% from 1972/73 to 1973/74. An increase of about 7% would be attributed to exchange rates and inflation. The comparison of actual and simulated corn and soybean prices leads to a similar conclusion.

By contrast, the real price of cotton increased almost 50% from 1972/73 to 1973/74. An increase of about 22% would be forthcoming from the effects of exchange rates and inflation. Note, however, the following year real cotton prices fell over 50%, illustrating the importance of factors other than exchange rates and inflation.

It has been suggested that the depreciation of the U.S. dollar has been a driving force behind trade and price increases during the seventies. Our results indicate much of the variability in commodity prices is attributable to other factors. However, to the extent that nominal-price insulation policies were pursued, domestic and foreign inflation emerge as important price-increasing forces for individual commodities.

Conclusions

The model and the application naturally have limitations. They abstract from many, possibly significant, factors. The partial-equilibrium elasticity approach admits no endogenous cross-price effects or absorption approach feedbacks. Choice of the reported exchange rates, price deflator, and assumed elasticities may raise issues of suitability. Expectations and lags (other than the one-year supply response lag) are not considered. Further, the computed exchange rate effects are not empirically validated and must be accepted with confidence proportionate to that one has in the assumptions of the model.

Limitations, however, should be only the sustenance, not the substance, of economic analysis. The computed exchange rate effects on U.S. commodity prices, despite abstractions, consider many factors heretofore ignored by researchers. The strength of the model lies in the simultaneous consideration of prices, consumption and production levels, and exchange rates for a nearly exhaustive set of major trading nations. The advantage of integrating alternative prices and intervention policies moves distinctly toward realism.

The strength of the empirical application, the tracing of exchange rate effects during much of the 1970s, lies in the diversity of results. The alluring simplicity of being able to announce exchange rate impacts on trade, hence prices, as simply large or small is rejected. Their size depends on the crop, the year, the countries considered, the degree of government influence on markets, the underlying elasticities, the price variable that is measured, whether real or nominal, the alternative prices considered, and importantly, the definition of an exchange rate effect.

This analysis does not limit the exchange rate effect on current U.S. price to the price change that occurs when a current period dollar revaluation alters demand. It goes beyond this: the price effect from a change in current supply, induced by past exchange rate changes, is part of the effect. The inclusion of the supply side moderated the overall exchange rate impacts. Differential inflation rates are also part of the effect.

If exchange rate changes reflect only differential rates of inflation, then under free trade, nominal commodity prices change but demand and supply do not. In contrast, if exchange rates are fixed, differential inflation rates cause demand and supply changes. An effect on real prices is induced.

Understanding exchange rate effects during the 1970s requires consideration of world inflation and price insulation policies. As the pervasiveness of nominal-price insulation policies increases, the impact of inflation and exchange rate changes on U.S. export demand and real commodity prices increases significantly.

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[8] The policy assigned to each country for each commodity was assumed to remain in effect over the 1971–77 period. An alternative approach would be to vary the assignments year by year.

References

Abbott, Philip C. "Modeling International Grain Trade with Government-Controlled Markets." *Amer. J. Agr. Econ.* 61(1979):22–31.

Bale, Malcolm D., and Bruce L. Greenshields. "Japanese Agricultural Distortions and Their Welfare Values." *Amer. J. Agr. Econ.* 60(1978):59–64.

Bredahl, Maury E., William H. Meyers, and Keith J. Collins. "The Elasticity of Foreign Demand for U.S. Agricultural Products: The Importance of the Price Transmission Elasticity." *Amer. J. Agr. Econ.* 61(1979):58–63.

Chambers, Robert G., and Richard E. Just. "A Critique of Exchange Rate Treatment in Agricultural Trade Models." *Amer. J. Agr. Econ.* 61(1979):249–57.

Fletcher, Stanley J., Richard E. Just, and Andrew Schmitz. "The Impact of Exchange Rates and Other Factors on North American Wheat Export Demand." *World Food Crisis: Issues and Policy Alternatives,* ed. Gordon C. Rausser. Amsterdam: North-Holland Publishing Co., in press.

Gallagher, Paul, Maury E. Bredahl, and Mike Lancaster. "Japanese and Western Europe Demand for U.S. Wheat." *Wheat Situation.* Washington, D.C.: USDA ESCS, May 1979.

Grennes, Thomas, Paul R. Johnson, and Marie Thursby. "A Critique of Exchange Rate Treatment in Agricultural Trade Models: Comment." *Amer. J. Agr. Econ.* 62(1980):249–52.

Hillman, Jimmye S. "Nontariff Barriers: Major Problem in Agricultural Trade." *Amer. J. Agr. Econ.* 60(1978):491–501.

Johnson, Paul R. "The Elasticity of Foreign Demand for U.S. Agricultural Products." *Amer. J. Agr. Econ.* 59(1977):735–36.

Johnson, Paul R., Thomas Grennes, and Marie Thursby. "Devaluation, Foreign Trade Controls, and Domestic Wheat Prices." *Amer. J. Agr. Econ.* 59(1977):619–27.

Konandreas, Panos, Peter Bushnell, and Richard Green. "Estimation of Export Demand Functions for U.S. Wheat." *West. J. Agr. Econ.* 1(1978):39–49.

Officer, Lawrence M. "The Purchasing Power Parity Theory of Exchange Rates: A Review Article." *IMF Staff Papers* 23(1976):1–60.

Ridler, Duncan, and Christopher A. Yandle. "A Simplified Method for Analyzing the Effects of Exchange Rate Changes on Exports of a Primary Commodity." *IMF Staff Papers* 19(1972):559–73.

Schuh, G. Edward. "The Exchange Rate and U.S. Agriculture." *Amer. J. Agr. Econ.* 56(1974):1–13.

Yandle, C. A. "Using the Commodity Method for Analyzing the Effects of Exchange Rate Changes—Some Considerations." *The Effects of Exchange Rate Adjustments,* ed. Peter B. Clark et al., pp. 341–54. Proceedings of a conference sponsored by the Office of the Assistant Secretary for International Affairs, U.S. Department of Treasury, Washington, D.C., 4–5 Apr. 1974.

Aggregated Personalistic Beliefs on Yields of Selected Crops Estimated Using ARIMA Processes

David A. Bessler

This study investigates the empirical relationships between the aggregated elicited probability distributions from individual farmers on yields of three 1977 California field crops and their data-based representations. The comparison suggests that for expected values, the ARIMA representations agree with the aggregated elicited distributions. However, for higher moments, the ARIMA processes do much poorer in representing the elicited distributions.

Key words: crop yields, stochastic processes, subjective probability.

The personalistic theory of probability is now well accepted in the literature on decision analysis. This theory differs from others (logical or frequency) by not attempting to specify a correct assessment. Any coherent assessment is admissable as long as it adequately reflects an individual's state of ignorance concerning an uncertain event. For instance, nothing obliges a decision maker to choose his probabilities according to relative frequency or some other a priori specified pattern. As the amount of information each person possesses varies, so too might his personalistic probabilities. This apparent lack of restrictions on probabilities presents no logical difficulty when the decisions of the individual are the object of analysis. Indeed, the theory only requires the decision maker adhere to a rather weak condition: probabilities should be evaluated such that it is not possible to bet with an individual and be guaranteed a priori of a gain or a loss.

The picture is somewhat muddied when we study the aggregate decisions of groups of individuals. For instance, the analysis of farmers' acreage response to price and other information variables is often given theoretical justification by referring to theories of individual firm behavior; a similar relationship is then argued to hold by analogy among macroinformation variables at the aggregate level. Where the individual behavior is thought to depend on personalistic probabilities, it is not obvious which particular personal probability (or combination of probabilities) ought to be used. In addition, even if one is able to arrive at a meaningful aggregate personalistic distribution using a notion of, say, the representative individual, it is likely that the observations on such will be difficult (or expensive) to obtain. For example, this might require that the analyst elicit personalistic probability distributions from a random sample of farmers every year and use their average distribution in an aggregate model.

An alternative procedure is to argue that individual and aggregated (representative) probabilities are closely related to their data-based representations. That is, one might argue that the personalistic distributions of individual agents are systematically related to the quantitative observations on one or more information variables. This is the procedure followed by Just in his analysis of California acreage supply response. Although he argued that individual production decisions were dependent upon personalistic (subjective) distributions of the individual decision makers, in the final analysis he had to relate these distributions to observations on quantitative data observed over time. He did not use elicited personalistic distributions of individual deci-

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sion makers in his final supply response estimation. Indeed, a time series of such observations would have been all but impossible for him to obtain.

Fortunately, this intuitive notion on the relationship between subjective probabilities and observed data has been worked out for a number of cases. For example, de Finetti (1937) in his seminal paper on probability, was able to show a relationship between exchangeable data and personalistic probability. In particular, he showed that for observations on exchangeable data—data for which the order of observation makes no difference to a decision maker—an evaluation of probability close to relative frequency follows in a coherent manner from an initial judgment. In language commonly used by Bayesian probabilists, we can restate de Finetti's point more intuitively by saying that as one observes more and more exchangeable observations, his prior distribution is swamped by the data. The case for nonexchangeable observations is similar conceptually—although there are numerous practical difficulties in arriving at a final distribution. Here the influence of order of observation on the probabilities must be considered. That is, for example, if the data tend to follow some pattern in the sequence of observation, one will want to take this into account in forming his probabilities. We can use de Finetti's (1937) own words to make the argument for nonexchangeable observations:

> The influence of the order on the evaluation of the probabilties . . . does not modify, indeed, the way in which the problem is posed and answered according to the subjectivistic conception; one will only be led, in the general case, to take account of the circumstances which in the case of exchangeability are (by definition) neglected. One can indeed take account not only of the observed frequency, but also of regularities or tendencies toward regularities which the observations can reveal. (p. 145)

The fact that analysts are able to work out a natural evolution of personalistic probabilities based on the sequential observation of data does not necessarily imply that decision makers follow or hold these derived probabilities. Such derivations are normative in the sense that if the analyst has identified the set of information deemed relevant by the decision maker and if the decision maker is rational, then he should form his probabilities close to the normative benchmark. However, there is nothing in such derivations which suggest that agents must or will formulate their probabilities according to any prespecified rule (de Finetti).

The purpose of this paper is to investigate the empirical relationship between personalistic probabilities and their data-based representations on 1977 yields of certain California field crops. The study could be carried out at the individual or microlevel. That is, the relationship between historical observations on yields received by individual farmers and their personalistic distributions on future yields could be studied and would generally be of interest to decision analysts. However, individual records on historical yields were not available for the sample of farmers in this study. Such data were available at higher levels of aggregation—county, region, and state. Because much of the work in economic modeling is at these higher levels of aggregation, a study of the relationship between aggregated personalistic distributions and their data-based representations also is of general interest.

Considerations on Aggregation

Because the analysis is made at the aggregate level, discrepancies between the data-based representations and the aggregated personalistic distributions can arise from numerous sources. To illustrate these, note figure 1, adapted from Ijiri. The micro or individual relations of interest ($f_{i,x}$) are between individual observations on historical data, ($x_{i,1}$, $x_{i,2}$, . . . , $x_{i,\tau}$), and individual, personalistic distributions on data in period $\tau + 1[\pi_i(x_{i,\tau+1})]$. Here we follow de Finetti's theory and allow this relationship to vary across each of the N individuals in the sample. Because we were not able to observe individual observations on the $x_{i,\tau}$'s of these microrelations, we focus on the relationship (F_X) between aggregates of historical data, (X_1, X_2, . . . , X_τ), and aggregates of individual personalistic distributions on data in $\tau + 1[\Pi(X_{\tau+1})]$. That is, we observe the relationship between the data and probabilities in the bottom line of figure 1.

$$\begin{tikzcd}(x_{i,1}, x_{i,2}, \ldots, x_{i,\tau}) \arrow[r, "f_{i,x}", "i=1,2,\ldots,N"'] \arrow[d, "\phi"'] & \pi_i(x_{i,\tau+1}) \arrow[d, "\psi"] \\ (X_1, X_2, \ldots, X_\tau) \arrow[r, "F_X"] & \Pi(X_{\tau+1})\end{tikzcd}$$

Figure 1. A general representation of an aggregation

Clearly, the function f can vary from individual to individual and from random variable to random variable. For instance, the relationship between exchangeable data and personalistic distributions is expected (de Finetti 1937) to be different from the relationship between nonexchangeable data and personalistic distributions. Thus, the particular function f must be allowed to be dependent on both the individual decision maker and the particular set of data which he brings to the assessment task. Analogously, the aggregate relation F is written such that it is dependent upon the data X (we could also write F such that it is dependent upon the group of individuals studied).

The aggregators ϕ and ψ take the microdata and microprobabilities into macrodata and macro (or aggregate) probabilities. The function ϕ, for instance, may be a simple convex combination with weights of $1/n$ assigned to each set of microdata. Similarly, ψ might be a convex combination of each microprobability.

Using the structure in figure 1, we can then restate the focus of our study as the relationships $(f_{i,x})$ which exist between observed data and personalistic probabilities. However, since we are not able to obtain long series of observations on microdata, we somewhat pragmatically study the relationship (F_X) between aggregate data and aggregated personalistic probabilities. Specifically, we describe a relation (F_X) between aggregate data and aggregate probabilities; we then investigate its reasonableness by comparing modeled aggregate probabilities based on aggregate data and actual aggregated probabilities, $\Pi(X_{\tau+1})$.

Modeling Time-Series Data

The class of models we investigate focuses on the probability structure itself. Procedures for doing this have been available for some time from numerous sources—probably the best known being the three-step procedure of Box and Jenkins.

A general univariate representation of the process Y_t (yield in period t) which we investigate is given as

$$(1) \quad \phi(B)(1-B)^d(Y_t-\mu)=\theta(B)a_t,$$

where the term $\phi(B)$ is an autoregressive operator of order p, given as

$$\phi(B)=(1-\phi_1B^1-\phi_2B^2-\ldots-\phi_pB^p),$$

$\theta(B)$ is a moving average operator of order q,

$$\theta(B)=(1-\theta_1B^1-\theta_2B^2-\ldots-\theta_qB^q),$$

where μ is the mean of the series Y_t, B is the lag operator $(B^iY_t=Y_{t-i})$, and a_t is a random error. Some suggest it useful to view a_t as an innovation that drives the series through time (Granger and Newbold 1975). The integer d is usually of low order 0, 1, or 2 (Granger and Newbold 1974). Writing equation (1) for the stationary series $y_t=(1-B)^d(Y_t-\mu)$, we can characterize the conditional probability distribution on y_t by its first two moments:

$$E(y_t|y_{t-1},y_{t-2},\ldots)=\phi(B)^{-1}\,\phi(B)E(a_t);$$

$$\mathrm{Var}\,(y_t|y_{t-1},y_{t-2},\ldots)=\sigma_{a_t}^2.$$

Note, for all periods preceding period t, $E(a_{t-i})$ will not, in general, equal zero. It will be given as a fixed, observable number which represents the unexplained portion of y_{t-i} in period $t-i$.

Box and Jenkins (p. 175) provide the following relations between the autocorrelations and partial autocorrelation functions of the series Y.

(*a*) For a nonstationary process the autocorrelation function tails off slowly.

(*b*) For a purely autoregressive process of order p, the autocorrelation function tails off and the partial autocorrelation function (Durbin, p. 235) has a cutoff after lag p.

(*c*) For a purely moving average process of order q, the autocorrelation function has a cutoff after lag q and the partial autocorrelation function tails off.

(*d*) For a mixed autoregressive process of order p and a moving average process of order q, the autocorrelation function is a mixture of exponential and damped sine waves after the first $q-p$ lags and the partial autocorrelation function is dominated by a mixture of exponential and damped sine waves after the first $p-q$ lags.

Box and Jenkins suggest comparing the estimated autocorrelation and partial autocorrelation functions applied to a particular series with the above patterns. The identification of values p, d, and q can oftentimes result in two or more distinctly different models (values of p, d, and q) which give reasonable representations of the empirical series (Box and Jenkins, p. 192; Wallis, p. 1487; or Priestley, p. 153). In such cases, researchers must rely on one of the many simplifying choice principles handed down from more philosophical works. These

include Occam's Razor, Parsimony (Box and Jenkins), or a Simplicity Postulate (Jeffreys). The models identified, using the procedures outlined above, can be estimated using iterative methods or nonlinear least squares. The usual conditions on the estimated parameters are that the autoregressive operator defines a stationary process and that the moving average operator defines an invertible process. In other words, the restrictions on estimated values of the parameters are that $\hat{\phi}(B)$ defines a process which is nonexplosive and $\hat{\theta}(B)$ defines a process which allows us to recover (observe) past values of a_t.[1]

Time-series data on yields were obtained from each California county from which our personalistic elicitations were obtained. We formed a regional series on each crop as a convex combination of each county—where weights were given by the rate of sampling for our personalistic elicitations. For example, our aggregate distribution on central valley wheat included three Merced County growers and five San Joaquin County growers. We combined the historical data on Merced and San Joaquin Counties, using the same 3/8 and 5/8 weights.

The estimated autocorrelation and partial autocorrelation functions on each series are given in table 1 for 1946–76 data.[2] The standard errors associated with low lags are approximately .18. From these estimates and their standard errors, we can make a number of observations. First, the functions for wheat and barley suggest different stochastic processes underlying central valley production and central coast production. The autocorrelations for the central valley grains remain high at relatively long lags (five or six); while those for the central coast show no strength at high lags. Second, it is not clear that different processes are required to model central coast sugar beets and central valley sugar beets. The autocorrelations for both series look similar. Third, note that the partial autocorrelation functions of both sugar beet series and central valley wheat and barley cut off at lag one; suggesting that if these series are modeled as stationary in their original levels, a first-order autoregressive scheme should be considered.

Due to the tailing off pattern in the autocorrelations for both sugar beet series and the series on Central Valley wheat and barley, we have used a difference transformation. The estimated autocorrelation and partial autocorrelation functions of the differenced series are given in table 2. The standard errors of the autocorrelations for low lags are approximately .18. Notice that the autocorrelations of each differenced series cut off at lag one. This suggests these differences are not generated by an autoregressive scheme in their first differences. The partial autocorrelations on both sugar beet series and the barley series show some evidence of tailing off. Thus, these may be generated by a first-order moving average process in their first differences. The series on Central Valley wheat exhibits no recognizable

[1] Hats (ˆ) refer to estimated values of the parameters included in the operator.

[2] The autocorrelation and partial autocorrelation functions are described in detail in Box and Jenkins, p. 64, and Durbin, p. 235.

Table 1. Estimated Autocorrelation and Partial Autocorrelation Functions on 1946–76 Time Series on Six California Field Crops

Commodity		Lags 1	2	3	4	5	6	7	8	9	10
Central valley wheat	A	.82	.72	.68	.63	.53	.47	.36	.26	.16	.10
	P	.82	.17	.15	.05	−.16	.01	−.22	−.08	−.15	.03
Central coast wheat	A	.44	.27	.18	.16	−.01	−.15	−.21	−.03	−.16	.04
	P	.44	.17	.06	.06	−.13	−.20	−.14	.15	−.07	.20
Central valley barley	A	.82	.67	.63	.61	.55	.40	.32	.20	.17	.11
	P	.82	−.00	.25	.07	−.03	−.28	.05	−.32	.24	−.19
Central coast barley	A	.04	−.14	.04	.26	.04	−.10	.03	.03	.21	.05
	P	.04	−.14	.06	.24	.05	.03	−.00	.05	−.20	.11
Central valley sugar beets	A	.58	.53	.48	.35	.25	.25	.02	.02	−.00	.09
	P	.58	.30	.15	−.06	−.10	.08	−.27	−.01	.03	−.04
Central coast sugar beets	A	.44	.35	.23	.41	.22	.20	.12	.19	.11	−.16
	P	.44	.20	.02	.33	−.08	.00	−.00	.01	−.01	−.24

Note: Autocorrelations for each commodity are given by the row labeled A; partial autocorrelations are given by row labeled P. Standard errors at low lags are approximately .18.

Table 2. Estimated Autocorrelation and Partial Autocorrelation Functions on the First Differences of 1946–76 Time Series on Four California Field Crops

Commodity		Lags 1	2	3	4	5	6	7	8	9	10
Central valley	A	−.50	.14	−.05	.03	−.02	.03	−.10	.10	−.20	.02
wheat	P	−.50	−.14	−.05	.00	.00	.03	−.10	.01	−.19	−.24
Central valley	A	−.34	−.22	.03	.01	.16	−.07	.14	−.32	.01	.13
barley	P	−.34	−.38	−.26	−.23	.04	.03	.34	−.11	−.15	−.26
Central valley	A	−.52	.01	.21	−.16	−.16	.33	−.18	−.01	.21	−.19
sugar beets	P	−.52	−.35	.05	.01	−.31	.05	.09	.04	.14	.03
Central coast	A	−.51	.09	−.29	.34	−.03	−.10	−.04	−.01	.20	−.13
sugar beets	P	−.51	−.23	−.51	−.17	.07	−.11	−.06	−.19	−.01	.02

Note: Autocorrelations for each commodity are given by the row labeled A; partial autocorrelations are given by row labeled P. Standard errors at low lags are approximately .18.

pattern. However, a first-order moving average process applied to its first differences ought to give us a parsimonious representation.

The models estimated for each commodity are given in table 3. As a check of the appropriateness of the estimated models, we have calculated the autocorrelations of the observed residuals—formed as the difference between the observed yield in any particular year and the yield predicted with our estimated model. These, along with the Q statistic (see Box and Pierce) are presented in table 4. The standard errors associated with the first two autocorrelations are approximately .18. In all models, the autocorrelations of the residuals are not significantly different from zero. Also, the Q statistics are below the critical chi-squared values—leading us not to suspect the adequacy of these representations. The time-series models summarized in table 3 are used as parsimonious representations for yields of the commodities studied.

Table. 3. Estimated Time-Series Models for 1946–76

Commodity	Model	Residual Standard Error
Central valley wheat	$(1 - B)Y_t = a_t - .33a_{t-1}$	.27
Central coast wheat	$Y_t = .43 + .35Y_{t-1} + a_t$	.13
Central valley barley	$(1 - B)Y_t = a_t - .38a_{t-1}$	.24
Central coast barley	$Y_t = .78 + .05Y_{t-1} + a_t$	.13
Central valley sugar beets	$(1 - B)Y_t = a_t - .48a_{t-1}$	2.56
Central coast sugar beets	$(1 - B)Y_t = a_t - .66a_{t-1}$	3.20

Note: All time-series models were estimated in terms of tons per acre. The forecasts on wheat and barley must be transformed to hundredweights per acre for comparisons with the subjective distributions in tables 6 and 7.

The Elicitation Experiment

Thirty farmers were selected from the files of the county farm advisors in ten California counties. These counties are in the large central valleys of California (San Joaquin and Sacramento valleys) and the central coast region. The elicitations took place in the fall of 1976 on the distributions of 1977 yield on barley, wheat, and sugar beets. Each elicitation took about one hour. The elicitations followed the procedure outlined in de Finetti (1965). We constructed a proper scoring rule and asked each assessor to distribute ten discrete probability units over the predetermined intervals given in table 5 (Stael von Holstein). The rule expressed potential payoffs to the assessor depending on the distribution of the discrete assessments and the average yield actually experienced by each farmer for the 1977 crop year. We allowed each farmer to modify this discrete distribution by shifting weight among intervals.

The individual elicited distributions are, in fact, distributions on separate random variables. That is, the yield from delta wheat land is not the same as Merced County wheat land. Soil, climate, managerial, varietal, and other differences exist among farming operations. Thus, each farmer responds to uncertainty inherent in his own operation. There is no reason to believe, a priori, that any agreement at all should exist among these individual distributions. Following the discussion of aggre-

Table 4. Autocorrelation Functions of the Observed Residuals from the Estimated Models

	Lags										
Commodity	1	2	3	4	5	6	7	8	9	10	Q^a
Central valley wheat	−.10	−.19	−.06	−.10	.17	.01	−.13	.00	.17	.15	4.71
Central coast wheat	−.05	.14	.08	.13	.01	−.13	−.18	.10	−.21	.10	4.77
Central valley barley	−.03	−.21	−.03	.05	.03	−.12	−.01	−.26	−.00	.20	5.14
Central coast barley	.02	−.16	.04	.27	−.02	−.10	.04	.05	−.22	.05	4.98
Central valley sugar beets	−.23	−.02	.17	−.18	−.14	.30	−.10	.01	.14	−.25	9.49
Central coast sugar beets	−.22	−.14	−.27	.30	−.00	−.13	−.09	.08	.21	−.08	9.38

[a] Q is distributed $\chi^2(9)$. The critical value at .05 level is 16.92.

gation given above, a more promising comparison can be made between the aggregated personalistic distributions and the statistical distributions based on aggregate historical data. We formed the aggregated personalistic distributions as a simple average of the individual distributions.

Comparison of Time-Series and the Elicited Distributions

The comparison statistical tests used here are ad hoc in nature. The classical theory of hypothesis testing is strictly couched in a frequency concept of probability. Thus, in testing the difference between two distributions (or their means), one makes inferences dependent on closeness relative to the number of observations or frequencies behind each distribution. Clearly, we cannot follow this line. The personalistic distributions are not frequency-based. In examining a similar problem, Winkler proposed using a quasi frequency-based test (in particular the Komogorov-Smirnov test) as evidence of agreement or disagreement among two or more subjective distributions. Our situation differs slightly in that, in the comparison of interest, we have one frequency-based distribution and one personalistic distribution. If we treat the aggregated personalistic distributions as fixed (which of course they are not), then we can apply standard frequency-based tests. However, such tests should be viewed with caution.

The time-series and aggregated subjective distributions on each commodity are given in figures 2.a–4.b. The smooth representations are for the time-series distributions obtained from table 3. The step functions represent the aggregated personalistic assessments on the yields of the same commodities.

The means of the times-series distributions and the personalistic distributions are given in table 6. Note the time-series distributions underpredict the mean yield in four of the six cases. Nevertheless, the ratio of the difference between the time-series mean and the aggregated personalistic mean to the standard error of the time-series mean (what is labeled t in table 6) is rather small in all cases. That is, the aggregated personalistic means fall within usually acceptable intervals around the time-series means.

An analysis of how well the entire aggregated personalistic distributions are modeled by the time-series distributions can be made using a quasi-Komogorov-Smirnov test. Winkler applies the procedure as one of his indica-

Table. 5. Subdivision of Yield Half-Line for Subjective Probability Assessments

Commodity	Number of Assessments	Unit of Measurement	Intervals for Assessment
Barley			
Coast	5	cwt./acre	$0 \leq Y_1 < 2.5 \leq Y_2 < \ldots < 100. \leq Y_{41} < \infty$
Valley	4	cwt./acre	$0 \leq Y_1 < 2.5 \leq Y_2 < \ldots < 100. \leq Y_{41} < \infty$
Wheat			
Coast	2	cwt./acre	$0 \leq Y_1 < 2.5 \leq Y_2 < \ldots < 100. \leq Y_{41} < \infty$
Valley	8	cwt./acre	$0 \leq Y_1 < 2.5 \leq Y_2 < \ldots < 100. \leq Y_{41} < \infty$
Sugar beets			
Coast	5	tons/acre	$0 \leq Y_1 < 2.0 \leq Y_2 < \ldots < 50. \leq Y_{28} < \infty$
Valley	6	tons/acre	$0 \leq Y_1 < 2.0 \leq Y_2 < \ldots < 50. \leq Y_{28} < \infty$

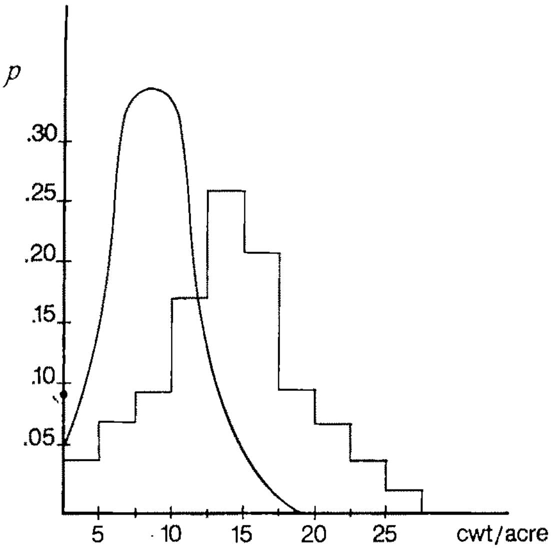

Figure 2a. Aggregate subjective and time-series distributions on 1977 California central coast wheat yield

tions of agreement among a group of subjective assessments. Other uses of the procedure include the work of Stael von Holstein. The procedure is analogous to the frequency-based Komogorov-Smirnov test of equality of two distributions. In table 7, we list the maximum vertical distance between the time-series and the aggregated personalistic cumulative distributions on each crop with the appropriate quasi-Komogorov-Smirnov test statistic.

The test summarized in table 7 suggests disagreement among the two distributions. That

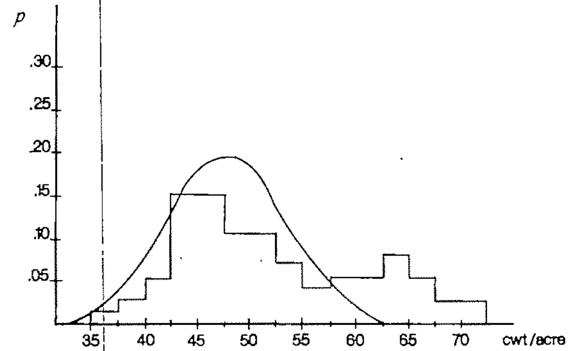

Figure 2b. Aggregate subjective and time-series distributions on 1977 California central valley wheat yield

is, treating the aggregated personalistic distributions as fixed, the chance that time-series distributions were generated by a process similar to the personalistic distributions is small.

Discussion

The analysis presented above should be qualified with a few comments. First, the time-series models used to represent the data assume the process generating the errors is normal. This presents at least two difficulties. First, the time-series distributions can suggest significant negative yields. That is, as in figure 2.a, it is possible for significant density to be nonzero at negative yields. In figure 2.a, we have accumulated all negative density and "stacked" it over zero. This seemed reasonable, yet it makes for an odd looking density function. In addition, the normality assumption does not allow the analyst to represent

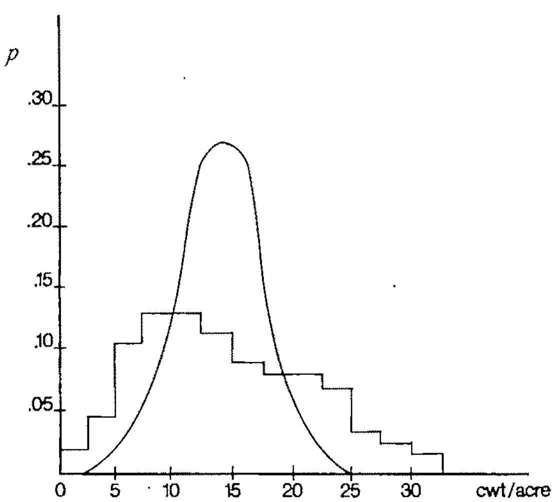

Figure 3a. Aggregate subjective and time-series distributions on 1977 California central coast barley yield

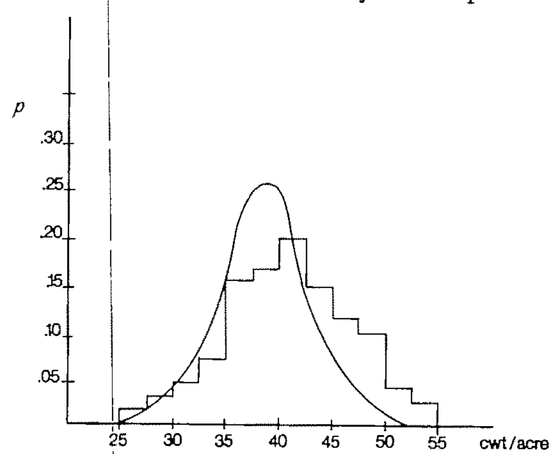

Figure 3b. Aggregate subjective and time-series distributions on 1977 California central valley barley yield

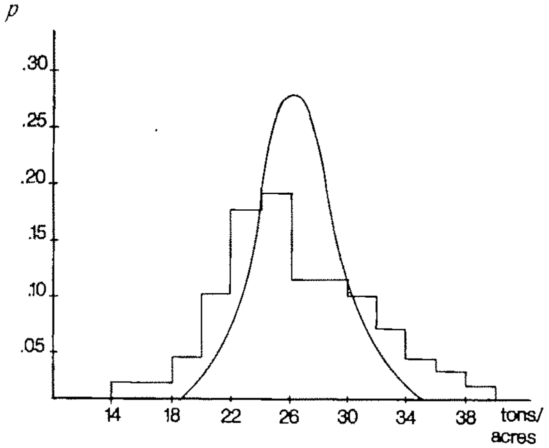

Figure 4a. Aggregate subjective and time-series distributions on 1977 California central valley sugar beet yield

skewed distributions. This point comes across in the figures and contributes to the large quasi-Kolmogorov-Smirnov statistics. Clearly, the aggregated personalistic distributions possess nonzero higher moments.

A second point which ought to be brought out is the static nature of our comparison. The analysis provides a "snapshot" of personalistic distributions at one particular point in time. A more complete and therefore preferred study would test the evolution of personalistic distributions through time, an important area for further study.

It is generally hoped that the aggregate representations of the macro variables "look something like" their micro counterparts. From the results of our study, we feel reasonably confident of using the ARIMA representations for the mean yield. Therefore, a suggestion similar to that made by Nerlove, that we model expectations using optimal statistical predictors (similar to our time series models) is not too disturbing. However, no such confidence can be expressed for modeling higher moments of the yield distribution. Of course the results presented here apply only to our particular commodities and to the set of thirty farmers interviewed.

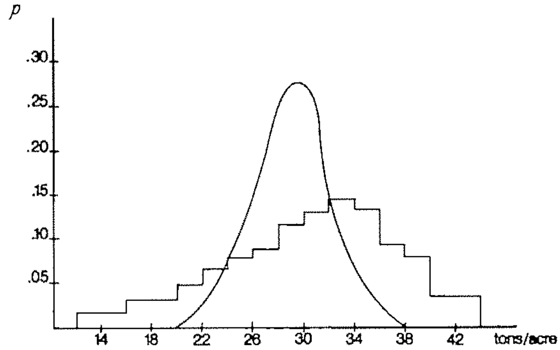

Figure 4b. Aggregate subjective and time-series distributions on 1977 California central coast sugar beet yield

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References

Box, G. E. P., and G. M. Jenkins. *Time Series: Forecasting and Control*, rev. ed. San Francisco: Holden-Day, 1976.

Table 6. Means and t-Statistics for Time-Series and Aggregated Personalistic Distributions on 1977 California Field Crop Yield

	Time-Series Mean	Aggregate Mean	t^a
Central valley wheat	47.80	52.78	.91
Central coast wheat	8.00	11.49	1.35
Central valley barley	38.40	42.51	.87
Central coast barley	15.32	15.01	.12
Central valley sugar beets	27.25	26.45	.31
Central coast sugar beets	28.83	29.84	.32

[a] t is calculated as $(P_t - P_s)/s_p$; where P_t and P_s are the time-series and subjective means, respectively, and s_p is the standard error of the time-series mean.

Table 7. Maximum Vertical Distance between the Cumulative Time-Series Distributions and the Aggregate Subjective Distributions on 1977 Yield for Selected California Field Crops by Regions

Crop	Maximum Vertical Distance	K/S^a
Central valley wheat	.35	1.95
Central coast wheat	.43	2.39
Central valley barley	.38	2.12
Central coast barley	.33	1.84
Central valley sugar beets	.24	1.34
Central coast sugar beets	.25	1.39

[a] K/S is calculated as $\sqrt{n}\,(\max|F_T - F_s|)$ where F_T is the cumulative time-series distribution and F_s is the cumulative personalistic distribution; n is the number of observations (31) used to form the time-series distribution. The critical value of K/S at a significance level of .10 is less than 1.23. Our calculated values are all above this critical value.

Box, G. E. P., and D. A. Pierce. "Distribution of Residual Autocorrelations in Autoregressive-Integrated Moving Average Time Series Models." *J. Amer. Statist. Assoc.* 65(1970):1509–26.

Durbin, J. "The Fitting of Time Series Models." *Rev. Int. Institute of Statist.* 28(1960):233–40.

de Finetti, Bruno. "Foresight: Its Logical Laws, Its Subjective Sources." *Studies in Subjective Probability,* ed. H. E. Kyburg and H. E. Smokler. New York: John Wiley & Sons, 1964 (reprinted from *Annales de l'Institute Henri Poincaré,* vol. 7, 1937).

———. "Methods for Discriminating Levels of Partial Knowledge Concerning a Test Item." *Brit. J. Math. and Statist. Psych.* 18(1965, part 1): 87–123.

Granger, C. W. J., and Paul Newbold. "Spurious Regressions in Econometrics." *J. Econometrics* 2(1974): 111–20.

———. "The Time-Series Approach to Econometric Model Building." Paper presented to the Seminar on New Methods in Business Cycle Research, Federal Reserve Bank of Minneapolis, 13–14 Nov. 1975.

Ijiri, Yuji. "Fundamental Queries in Aggregation Theory." *J. Amer. Statist. Assoc.* 66(1971):766–82.

Jeffreys, H. *Theory of Probability,* 3rd ed., rev. London: Oxford University Press, 1967.

Just, Richard E. *Econometric Analysis of Production Decisions with Government Intervention: The Case of California Field Crops.* Giannini Foundation Mono. No. 33, University of California, Berkeley, 1974.

Nerlove, Marc. "The Dynamics of Supply: Retrospect and Prospect." *Amer. J. Agr. Econ.* 61(1979):874–88.

Priestley, M. B. "Comments on the Paper: 'Experience with Forecasting Univariate Time Series and the Combination of Forecasts' by P. Newbold and C. W. J. Granger." *J. Royal Statist. Soc.* Ser. A, 137(1974):131–65.

Stael von Holstein, Carl-Axel S. *Assessment and Evaluation of Subjective Probability Distributions.* Stockholm: Economic Research Institute, Stockholm School of Economics, 1970.

Wallis, K. "Multiple Time Series Analysis and the Final Form of Econometric Models." *Econometrica* 45(1977):1481–98.

Winkler, Robert. "The Assessment of Prior Distributions in Bayesian Analysis." *J. Amer. Statist. Assoc.* 62(1967):776–800.

Estimation and Optimal Control of an Uncertain Production Process

C. Robert Taylor and Jean-Paul Chavas

Three alternative decision rules for estimation and control of an uncertain production process are examined. One is a certainty equivalence strategy whereby an optimal rate based on current estimates of production parameters is used throughout the planning horizon. A second is updated certainty equivalence, a passively adaptive strategy. Third is an actively adaptive control formulation. Monte-Carlo simulation results show that the passively adaptive strategy outperforms the others. For the cases simulated, the actively adaptive approximation to the information state for a dual control problem is not good enough to establish superiority of this sophisticated strategy for all problems.

Key words: dual control, uncertain production processes.

Farm level recommendations regarding economically optimal input rates often are based on response functions estimated with data obtained from carefully controlled experimental plots. While optimal rates estimated with experimental data may be best for experimental plots, they often appear suboptimal for actual farm conditions (Taylor and Swanson). A response function for an experimental plot can diverge from a response function experienced under field conditions for a variety of reasons, including soil type differences, different topsoil thickness, micronutrient availability, precision of control over other inputs, and timing of field operations. Further decision complications arise when a new technology, such as a plant variety or tillage system or a whole production system, is introduced. In these cases, little if any experimental data are available on which to base optimal input rate recommendations.

Divergence of experimental fertilizer response data from actual farmer experiences and the lack of data for new production technologies suggest that individual farmers have to rely on their own experience in choosing optimal input rates. In this context, any input decision may have two roles. First, it is used to control the mean and higher moments of profit. Second, it will influence the generation of new observations which will allow the farmer to learn about his particular production technology and thus make better decisions in the future.

Recent articles by Feldstein, and Just and Pope examined economic implications of uncertain production technology. However, they did not introduce learning and adaptive optimization into the decision framework. The objective of this paper is to investigate alternative decision rules for estimation and optimal control of an uncertain process. Three strategies that could be used for making recommendations to a farmer about optimal input use are examined. All strategies involve using the same input rate for the whole field in a given crop year.

The first strategy considered is a certainty equivalence (CE) strategy whereby an optimal rate based on current estimates of the parameters of the response function is used throughout the planning horizon. With this strategy, there is no updating of parameter estimates as new observations become available. The second strategy examined is updated certainty equivalence (UCE), which differs from a CE strategy only in that parameter estimates are updated and optimal rates revised accordingly each time a new observation becomes available. UCE is a passively adaptive control strategy in the sense that current decisions are made without recognizing how they will influence learning. It belongs to the class of open-loop feedback controls. An actively adaptive control formulation (TBM) advanced by Tse, Bar-Shalom, and Meier is the third

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strategy considered. This "wide-sense" adaptive model explicitly recognizes how current decisions will influence future knowledge. This strategy is dual in nature because the input level is chosen for both control and estimation of the model.

Organization of the remainder of the paper is as follows: section two presents the response model, while theoretical aspects of alternative control strategies are discussed in section three. Monte-Carlo simulation results, which provide the basis for the evaluation and comparison of each strategy, are presented in section four. Concluding remarks and suggestions for further research into adaptive optimization are given in the final section.

The Model and Alternative Control Strategies

We assume a quadratic response function that can give a local second degree approximation to any production function at time k:

$$(1) \quad y_k = b_1 + b_2 x_k + b_3 x_k^2 + e_k,$$

where y_k is per acre yield obtained in season k; x_k is per acre input rate in season k; b_1, b_2, b_3 are parameters characterizing the response function with $b_2 > 0$ and $b_3 < 0$; and e_k is normally and independently distributed noise in the response function attributed to weather variability or any random factor.[1] The error is assumed to be distributed with mean zero and variance

$$E(e_k, e_{k'}) = \begin{cases} \sigma^2 \text{ for } k = k' \\ 0 \text{ for } k \neq k' \end{cases}.$$

For the problem at hand, it is assumed that the form of the response function is known with certainty; however, there is incomplete knowledge about the parameters b_1, b_2, b_3. It is further assumed that the producer has available prior information (mean vector and covariance matrix) on the parameters b_1, b_2, b_3, and on the noise e_k. This information can be based objectively on previous observations on the field to which function (1) applies. Alternatively, the information can be of a subjective nature. Let the prior information on the parameters (b_1, b_2, b_3) at time k be denoted by $B(k) = [b_1(k), b_2(k), b_3(k)]'$, with prior covariance matrix Σ_k. Moreover, let s_k^2 be an unbiased estimate of the variance, σ^2, at time k.

[1] Process noises could also be included. However, we will assume no process noise throughout the paper.

Assuming risk neutrality, the performance measure is the present value of expected per acre profits:

$$(2) \quad E(\Pi) = \sum_{k=1}^{N} \left(\frac{1}{1+i}\right)^k E(Py_k - Rx_k),$$

where i is the interest rate, N is the planning horizon, and P and R are output and input prices, respectively. The parameters i, N, P, and R are assumed fixed (nonrandom). Thus the only uncertainty in the model is about the vector of production parameters (b_1, b_2, b_3). Thus the problem under consideration is one of uncertain technology with random parameters.

Certainty Equivalent Strategy (CE)

Letting the current decision period be $k = 1$, the CE strategy is to compute the optimal input rate for all future periods as

$$(3) \quad x^*_k = \frac{R/P - b_2(0)}{2b_3(0)},$$

where P is per unit price of the output, and R is per unit price of the input. Obviously this is a naive strategy that does not allow for any time of learning over time. It is included here primarily to show how the other strategies perform in comparison.

Updated Certainty Equivalent Strategy (UCE)

UCE differs from a CE strategy in that parameter estimates are updated each time a new observation on output y_k becomes available. Thus,

$$(4) \quad x^*_{k+1} = \frac{R/P - b_2(k)}{2b_3(k)}.$$

For this problem, the Kalman filter can be used to update the parameter estimates at time k based on the prior information $B(k-1)$, Σ_{k-1}, and on the observations for period k.

$$(5) \quad B(k) = B(k-1) + \Sigma_{k-1} X'_k(X_k \Sigma_{k-1} X'_k + s_{k-1}^2 I)^{-1}[Y_k - X_k B(k-1)],$$

where $X_k = (1, x_k, x_k^2)$. If the prior information represented by $B(k-1)$ and Σ_{k-1} is estimated by ordinary least squares (OLS) from sample information obtained before time k, the Kalman filter estimator, equation (5), is equivalent to an OLS estimator at time k and is an unbiased, minimum variance estimator of the population parameters (Chow 1975).

The UCE strategy does learn over time, but learning is of a passive nature since anticipation of learning is not used in calculating the current input rate.

Wide-Sense Actively Adaptive Strategy (TBM)

Various active adaptive schemes have been proposed in the literature (MacRae 1972, 1975; Chow 1975, 1976a,b; Tse, Bar-Shalom, and Meier; Bar-Shalom and Tse). Such schemes are intuitively appealing because they explicitly recognize the need for learning (Rausser, p. 483). Current decisions consider both control and estimation of the model. Current and future uncertainty are introduced in the decision rules, thus increasing information for improved performance in the future. Because of the closed-loop nature of actively adaptive strategies, the dimensionality (usually infinite) of the control problem is such that solution for an optimal strategy is computationally prohibitive. Consequently, workable active adaptive schemes are only approximations.

As noted by Rausser, the most widely publicised actively adaptive scheme is based on the work of Tse, Bar-Shalom, and Meier. Reasoning behind the TBM approach is too lengthy to reiterate in this paper. But, Rausser has provided a concise summary:

> In essence, the wide-sense dual control procedure advanced by these authors . . . decomposes the complete adaptive control problem into three components (*a*) current control, (*b*) future deterministic control, and (*c*) a future perturbation control. The perturbation, or experimental control component, is partitioned into a caution and probing term. The caution term reflects the effects of uncertainty at time *k* and subsequent system noise on the criterion function. The probing term summarizes the effect of uncertainties when subsequent decisions are made. (p. 483)

To avoid the infinite dimensionality associated with maintaining all features of the information state for adaptive control, the TBM approach approximates this state by maintaining only the updated estimates of the means and covariances of the parameters. Estimates can be updated with the Kalman filter (Chow 1975), given by equation (5). In the TBM approach, the optimal future benefit or cost-to-go is approximated up to the end of the planning period. Since the control of a linear quadratic Gaussian problem is easy to solve, the nonlinear joint control estimation problem is accordingly modified. TBM associates with each control at present time (k) a future fictitious nominal control sequence. For each nominal control trajectory, there is a corresponding nominal state trajectory and approximate trajectory of variances and covariances. Perturbation analysis carried out around these nominals from which approximate costs-to-go are obtained that explicitly reflects future learning and control performance.

In our case, the future nominal trajectory is chosen as the certainty equivalence (CE) solution. The objective function is to maximize the present value of net returns, which for the TBM model is the sum of three terms: the deterministic part, the caution term, and the probing term. The deterministic part is comprised of current expected profit and the discounted future profit along the nominal path. Because discounted future profits along the nominal path is not dependent on the current input rate, the deterministic component of the TBM objective function differs from the CE objective function only by a constant. The probing term is a weighted sum of the future elements of the covariance $\Sigma_{0,k+1}, \ldots, \Sigma_{0,N}$ along the nominal. In the maximization case, it can be shown that the probing term is always negative. Thus, added uncertainty tends to decrease the value of the objective function. Current control that decreases future uncertainty therefore makes the firm better off, which corresponds to the probing effect. The caution term always has the opposite sign of the probing term. In the absence of measurement noise, it is a weighted sum of the elements of the updated covariance matrix of the parameter estimates for the decision period k, Σ_k. The caution term is necessarily positive in a maximization framework, and thus tends to increase the value of the objective function and balance the probing effect. Thus, current uncertainty tends to imply more "cautious" decisions.

The input level that maximizes the three-part objective function is the optimal solution of the TBM dual control approximation. An illustration of the shape of the TBM objective function as well as shapes of the terms which comprise the function are given in figure 1. Note in figure 1 that the TBM objective function has three peaks, at input rates of approximately 50, 75, and 100. Two of these peaks are outside the range of prior information, while the third peak is at the upper limit of prior values of X. Although not always the

case, two peaks outside the range of prior information is rather typical for the problem considered here when prior information is sparse. Thus, with sparse information, the TBM approach typically leads to experimentation in the sense of selecting values outside the range of prior information. As information increases, the TBM objective function approaches the CE objective function, and both approach true profit.[2]

It is interesting to compare the functions shown in figure 1 to the illustration given by Bar-Shalom and Tse (p. 331) for a different problem. They showed all functions as being monotonic, while for our problem some of the terms have ranges of both increasing and decreasing values.

Monte-Carlo Simulation Results

Because the objective function for any strategy is approximated, the optimal control never can be exactly obtained. In order to evaluate the performance of each strategy, a Monte-Carlo simulation was carried out. Previous simulation experiments using various static and dynamic systems have not clearly demonstrated that the more sophisticated control strategies are always superior to the other strategies (Bar-Shalom and Tse, and Rausser). In this section, we examine the comparative performance of the three strategies discussed previously for a response function that appears to reflect fairly accurately dryland grain sorghum response to nitrogen fertilization in the Texas Blackland Prairies. The assumed true response function is

$$y = 2600 + 33x - .15x^2 + e, \tag{6}$$

where e is assumed to be normally distributed with mean zero, y is yield in pounds per acre, and x is nitrogen fertilizer application rate in pounds per acre. Assumed prices were \$.04 per pound of grain and \$.20 per pound of fertilizer. For the above parameters, the optimal fertilization rate is 93.3 pounds per acre. A maximum of 110 pounds and a zero minimum were assumed as constraints on the fertilization rate.

Since the profit function based on production function (6) is rather flat—suggesting that different input rates may have a small impact on the profit level and that experimentation may not be profitable—the following hypothetical production function which has a more peaked profit function was also examined:

$$y = -4300 + 185x - x^2 + e. \tag{7}$$

For the simulations, the amount of prior information and the standard error of e were varied to examine how they influenced performance of the various strategies. Standard errors of 150 pounds and 450 pounds, and prior information uniformly distributed over the ranges 40–85 and 67–85 were considered for production function (6). For function (7) both standard errors were evaluated, but only with prior information over the range 67–85. In all cases, it was assumed that ten prior observations on x were available.

For each simulation, standard normal deviates were generated to yield observations on y, first for the ten prior observations and then for each year in the twenty-five-year simulation period. The same sets of deviates were used for all strategies evaluated.

Because of several local peaks for the objective functions (see figure 1) for the actively adaptive strategy (TBM), a grid search in five-pound increments was used to locate the neighborhood of the global maximum. Then, a finer grid search in one-pound increments was used. A finer grid search was not used for the

[2] A paper that gives a derivation of the TBM wide-sense dual control approximation, specialized for the problem considered in this study, is available from the authors.

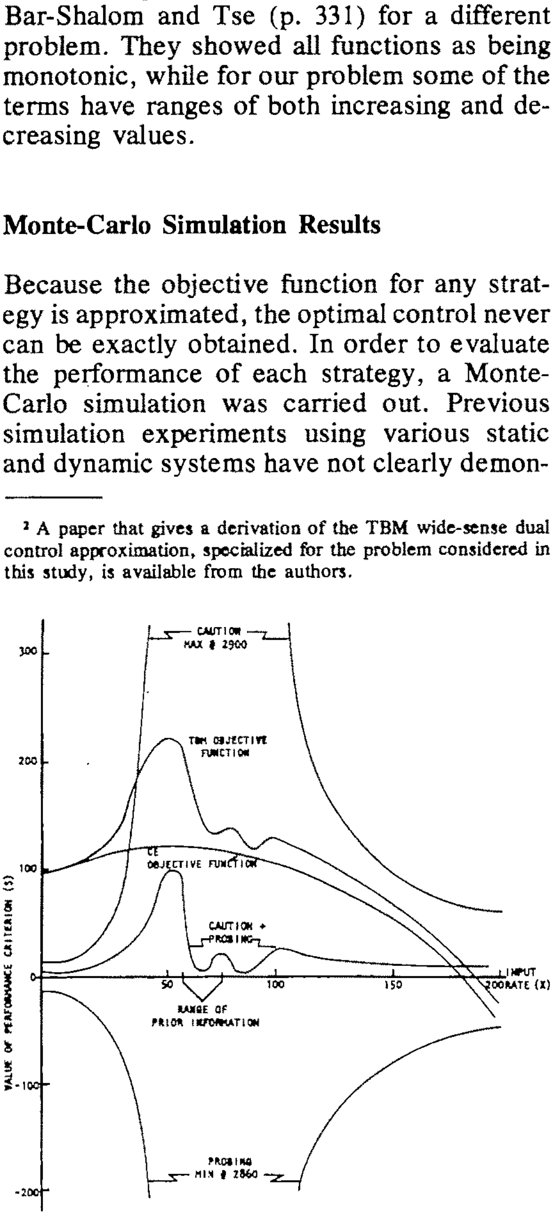

Figure 1. An illustration of the objective function, caution, probing, and deterministic terms for the TBM model

Table 1. Simulated Performance of Alternative Strategies for Different Prior Information and Error Variances

	Present value of returns above fertilizer cost for 25 years averaged over 20 simulations with 10 prior observations,[a] with:					
	(6)				(7)	
	x Uniformly Distributed over the Range 40–85		x Uniformly Distributed over the Range 67–85		x Uniformly Distributed over the Range 67–85	
Strategy	$\sigma = 150$	$\sigma = 450$	$\sigma = 150$	$\sigma = 450$	$\sigma = 150$	$\sigma = 450$
	($)					
CE	1,542.45	1,531.96	1,543.78	1,539.94	1,425.56	1,403.08
UCE	1,546.94	1,532.20	1,547.09	1,535.17	1,495.61	1,468.38
TBM	1,534.58	1,521.44	1,534.31	1,504.22	1,438.52	1,386.57
OPTIMAL	1,559.25	1,556.97	1,559.25	1,556.97	1,512.21	1,509.93

[a] A 10% interest rate was used to discount future returns.

whole range of x values because of the high cost of solving for the TBM strategy.

The present value of profit averaged over twenty simulations is given in table 1 for each strategy for the cases considered. Surprisingly, UCE resulted in higher profits than any of the other strategies in all cases simulated. For the relatively flat production function (6), CE resulted in higher profits than TBM in all four cases. However, TBM outperformed CE in one of two cases using the more peaked production function (7).

For a few simulations where the prior estimate of b_3 was positive, the UCE strategy tended to lock in to the maximum permissible rate of 110 pounds. If the UCE strategy was modified so that there would be a variable maximum rate over time, learning would occur and profits undoubtedly would be higher. Or, a restricted estimator could be used to prevent positive b_3 coefficients. But a restriction of this type does not appear reasonable for some problems as the farmer does not know a priori that he is not in stage one of production. If no upper limit of any kind is placed on x, then UCE or TBM will blow up when a positive b_3 is encountered.

Concluding Remarks

This paper has investigated alternative ways of taking into consideration the value of information obtained from experimenting about a static nitrogen fertilizer response on dryland grain sorghum. As expected, results show that greater uncertainty tends to lower expected profit, indicating that more information (less uncertainty) improves welfare. Unexpectedly, the passively adaptive strategy (UCE) performed better than the sophisticated actively adaptive strategy (TBM) in all cases considered, including cases for a profit function that is more peaked than one would expect for the problem considered. Because the TBM objective function is higher than the UCE objective function, one might conclude that TBM will always outperform UCE. However, the approximated objective function obtained from theoretical considerations is not the profit function realized by applying a TBM strategy. Because the performance of TBM was slightly worse than UCE, we conclude that the TBM approximation to the information state for a dual control problem of the type considered here is not good enough to establish superiority of TBM for all problems. Two reasons may be advanced to explain the surprisingly poor performance of the more sophisticated algorithm, TBM. First, the choice of the certainty equivalent solution for the nominal path may not be appropriate. Second, the quadratic approximation along the nominal may disregard some information that would be relevant. Thus the TBM approach, while purporting to measure the value of information, does not seem to give a good approximation to the control problem.

A limit of this study is that it relies on the use of the least squares estimation method. Recently, Klein et al. have argued that it is inappropriate to use maximum likelihood estimates to make decisions because the loss function of the statistical estimation is usually different from the utility function of the decision maker. Although this paper has considered learning about the production uncer-

tainty, the implication of the estimation technique has not been investigated and is left for further research.

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References

Bar-Shalom, Y., and E. Tse. "Caution, Probing and the Value of Information in the Control of Uncertain Systems." *Ann. Econ. and Social Measure.* 5(1976):323–36.

Chow, G. C. "An Approach to the Feedback Control of Nonlinear Econometric Systems." *Ann. Econ. and Social Measure.* 5(1976a):297–310.

———. "A Solution to Optimal Control of Linear Systems with Unknown Parameters." *Rev. Econ. and Statist.* 57(1975):338–45.

———. "The Control of Nonlinear Econometric Systems with Unknown Parameters." *Econometrica* 44 (1976b):685–95.

Feldstein, M. S. "Production with Uncertain Technology: Some Economic and Econometric Implications." *Int. Econ. Rev.* 12(1971):27–38.

Just, R. E., and R. D. Pope. "Stochastic Specification of Production Functions and Economic Implications." *J. Econometrics* 7(1978):67–86.

Klein, R. W., L. C. Rafsky, D. S. Sibley, and R. D. Williz. "Decisions with Estimation Uncertainty." *Econometrica* 46(1978):1363–87.

MacRae, E. C. "An Adaptive Learning Rule for Multiperiod Decision Problems." *Econometrica* 43 (1975):893–906.

———. "Linear Decision with Experimentation." *Ann. Econ. and Social Measure.* 1(1972):437–47.

Rausser, G. C. "Active Learning, Control Theory, and Agricultural Policy." *Amer. J. Agr. Econ.* 60 (1978):476–90.

Taylor, C. R., and E. R. Swanson. "Experimental Nitrogen Response Functions, Actual Farm Experience and Policy Analysis." *Ill. Agr. Econ.* 13(1973):26–32.

Tse, E., Y. Bar-Shalom, and L. Meier. "Wide-Sense Adaptive Dual Control of Stochastic Nonlinear Systems." *IEEE Trans Automatic Control* AC-18 (1973):98–108.

Perfect Aggregation and Disaggregation of Complementarity Problems

Quirino Paris

Perfect aggregation of linear complementarity problems is possible under the notion of constrained consistency. This notion—which also can be interpreted as a disaggregation rule—requires restrictions on the domain of the microvariables to be aggregated. The linear complementarity problem includes symmetric and asymmetric quadratic programming, linear programming, and two-person, nonzero-sum games. Hence, all these mathematical programming structures admit consistent aggregation and disaggregation of their primal and dual variables.

Key words: constrained consistency, linear complementarity problem, perfect aggregation, symmetric quadratic programming.

The problem of finding consistent procedures for aggregating economic models remains a pressing issue of methodological and empirical analyses. In the area of economic models specified within the framework of mathematical programming, the discussion of aggregation procedures has been limited essentially to linear programming (LP), with the contributions of Day, Miller, Lee, Paris and Rausser, Guccione and Oguchi. Only recently Oguchi and Guccione presented a brief treatment of the aggregation problem in asymmetric quadratic programming models.

This paper attempts to expand the discussion of consistent aggregation and disaggregation methods to all the mathematical programming models from the class of linear complementarity problems. Such a class is vast and includes (among others) symmetric and asymmetric quadratic programming, linear programming, and two-person, nonzero-sum game problems.

The linear complementarity (LC) problem consists in finding nonnegative vectors $\mathbf{z}$ and $\mathbf{w}$, such that

(1) $$-\mathbf{q} = -\mathbf{w} + M\mathbf{z}, \text{ and}$$

(2) $$\mathbf{w}'\mathbf{z} = \mathbf{0},$$

where $\mathbf{q}$ is an $r \times 1$ vector and M is a given $r \times r$ real matrix. The linearity of the problem is expressed by (1), while its complementarity feature is exhibited by (2). For a thorough discussion of the LC problem, one may consult Lemke (1968). Interest in the general complementarity structure is based on the fact that any proposition established about the LC problem is valid also for the mathematical programming models which are special cases of it.

All the microsystems in previous discussions of the aggregation problem within the framework of programming models are special cases of the above formulation. Consider, in fact, Day's linear programming formulation as re-elaborated by Guccione and Oguchi. These authors discuss an aggregation problem where a microsystem of K firms exhibits identical technologies, $A_k \equiv A_a$, $k = 1, \ldots, K$, where inputs and outputs must be consolidated into a consistent aggregate LP model and where, furthermore, the microvectors of resource constraints, $\mathbf{b}_k$, and the microvectors of net revenue, $\mathbf{c}_k$, are proportional to the corresponding aggregate (macro) constraint and revenue vectors, $\mathbf{b}_a$ and $\mathbf{c}_a$. In other words, $\mathbf{b}_k = \lambda_k \mathbf{b}_a$ and $\mathbf{c}_k = \gamma_k \mathbf{c}_a$, with scalars $\lambda_k \geq 0$, $\gamma_k \geq 0$; $k = 1, \ldots, K$.

It is simple to accommodate the LP microproblem of Day and Guccione and Oguchi into the linear complementarity framework (1) and (2). First of all, the block-diagonal matrix A, defined as follows:

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$$A = \begin{bmatrix} A_1 \equiv A_a & 0 & \dots & 0 \\ 0 & A_2 \equiv A_a & \dots & 0 \\ \dots & \dots & \dots & \dots \\ 0 & 0 & \dots & A_k \equiv A_a \end{bmatrix},$$

represents the K firms' linear technologies which Day chose to be identical; the set of technologies in a microproblem. Similarly, the microresource vectors, $\mathbf{b}_k$, and the net revenue vectors, $\mathbf{c}_k$, are stacked to form the vectors $\mathbf{b}$ and $\mathbf{c}$, respectively; that is, $\mathbf{b}' = (b'_1, b'_2, \dots, b'_K)$, $\mathbf{c}' = (c'_1, c'_2, \dots, c'_K)$.

Now, the LP microproblem (or microsystem) of Day, Guccione and Oguchi, and others, can be stated compactly as in (1) and (2) by simply defining

$$\mathbf{q} = \begin{bmatrix} b \\ -c \end{bmatrix}, M = \begin{bmatrix} 0 & -A \\ A' & 0 \end{bmatrix},$$

$$\mathbf{z} = \begin{bmatrix} \mathbf{y} \\ \mathbf{x} \end{bmatrix}, w = \begin{bmatrix} \mathbf{v} \\ \mathbf{u} \end{bmatrix},$$

where $\mathbf{y}' = (y'_1, y'_2, \dots, y'_K)$, $\mathbf{x}' = (x'_1, x'_2, \dots, x'_K)$ are stacked solution vectors of the LP dual pair of microproblems, and $\mathbf{v}' = (v'_1, v'_2, \dots, v'_K)$, $\mathbf{u}' = (u'_1, u'_2, \dots, u'_K)$ are the stacked slack vectors of the dual and primal microconstraints, respectively.

It should be clear, therefore, (although the notation and the structure is slightly different) that we wish to deal also with the aggregation problems as discussed in the literature by Day, Miller, Lee, Paris and Rausser, Guccione and Oguchi, and Oguchi and Guccione. Indeed, the formulation is substantially more general than those previously proposed because it does not require a priori the identity of the firm technologies. The block-diagonal matrix A, in fact, can accommodate firm technologies, A_k, $k = 1, \dots, K$, which are completely different from one another. The difference involves both the technical coefficients and the dimensionality of the matrices A_k, $k = 1, \dots, K$, as subsequently illustrated.

Notice, finally, that the formulation specified in (1) and (2) encompasses also the aggregation problem with nondiagonal (full) matrices A, as in the case of input-output models, or of very large programming models of the economy, or the consolidation of two-person, nonzero-sum games.

In what follows, we first specify the aggregation problem for the linear complementarity problem following the conventional viewpoint of stating a micro and a macro (aggregate) system together with the aggregation relations. Except for the matrix notation, this specification is entirely similar to that encountered in the literature. As indicated by Guccione and Oguchi, the aggregation of mathematical programming models must be considered under some conditions of constrained consistency. We specify the constrained consistency in rather general terms. Next, we establish the fundamental aggregation and disaggregation theorem. Fourth, we apply the aggregation conditions so derived to symmetric and asymmetric quadratic programming and to linear programming. Finally, we demonstrate the feasibility of the procedure with a numerical example.

The Aggregation Problem

Consider problem (1) and (2) as the micro-linear complementarity model to be consolidated. In other words, instead of solving (1) and (2), the researcher wishes to solve a problem of the same structural form but of smaller dimensions. This aggregation problem occurs, for example, when a researcher seeks to represent the behavior of several microunits (a microsystem in Ijiri's terminology) by a single aggregate model (the macrosystem). Such an aggregate or macroproblem is that of finding nonnegative vectors $\mathbf{z}_a$ and $\mathbf{w}_a$, such that

(3) $$-\mathbf{q}_a = -\mathbf{w}_a + M_a\mathbf{z}_a, \text{ and}$$

(4) $$\mathbf{z}'_a\mathbf{w}_a = \mathbf{0},$$

where $\mathbf{q}_a$ is an $s \times 1$ vector considered to be arbitrary, M_a is a given $s \times s$ matrix and $s < r$.

Again, the aggregate LC problem (3) and (4) includes, as special cases, all the aggregate (macro) specifications discussed in the literature on aggregation of mathematical programming models.

The notion of constrained consistency with which aggregation of mathematical programming models must be associated was originally discussed by Ijiri. Very briefly, a one-to-one correspondence between the solution sets of the micro and of the aggregate problem does not exist. Hence, the researcher is left with the alternative of establishing a one-to-one correspondence between the solution set of the aggregate problem and a solution subset of the microproblem. How such a subset is to be selected is, in general, a matter of empirical interest. Obviously, a researcher would like to impose minimal restrictions on the solution set

of the microproblem, those strictly necessary to achieve perfect aggregation. The definition of constrained consistency adopted in this paper is now formulated.

Constrained Consistency

The domain of the vector $\mathbf{q}$ and variables $\mathbf{w}$ and $\mathbf{z}$ of the microproblem is restricted as follows:

$$\mathbf{q} = U\mathbf{q}_a, \tag{5}$$

$$\mathbf{w} = U\mathbf{w}_a, \tag{6}$$

$$\mathbf{z} = T\mathbf{z}_a, \tag{7}$$

where U and T are nonnegative matrices of full rank and of dimensions $r \times s$. It is obvious that conditions (5), (6), and (7) can be interpreted, alternatively, as a specification of perfect disaggregation.

The adopted definition of constrained consistency follows the same specification as that employed by all authors who discussed the aggregation problem in mathematical programming. Once again, consider, for example, the constrained consistency in the LP aggregation problem of Day with the notation of Guccione and Oguchi. The proportionality requirement between micro and macro vectors $\mathbf{b}_k = \lambda_k\mathbf{b}_a$, and $\mathbf{c}_k = \gamma_k\mathbf{c}_a$; $k = 1, \ldots, K$ is nothing more than condition (5) where the matrix U is defined as

$$U = \begin{bmatrix} \lambda_1 I & 0 \\ \lambda_2 I & 0 \\ \vdots & \vdots \\ \lambda_K I & 0 \\ 0 & \gamma_1 I \\ 0 & \gamma_2 I \\ \vdots & \vdots \\ 0 & \gamma_K I \end{bmatrix},$$

and $\mathbf{q}' = (\mathbf{b} - \mathbf{c})'$, $\mathbf{q}_a = (\mathbf{b}'_a - \mathbf{c}'_a)$.

Similarly, Day's and Guccione and Oguchi's discussions require that the primal and dual microsolutions be proportional to the corresponding macrosolutions $\mathbf{x}_a$ and $\mathbf{y}_a$. That is, $\mathbf{x}_k = \beta_k\mathbf{x}_a$, $\mathbf{y}_k = \alpha_k\mathbf{y}_a$, where α_k and β_k are nonnegative scalers. This specification is analogous to condition (7), where $\mathbf{z}' = (\mathbf{y}', \mathbf{x}')$, $\mathbf{z}'_a = (\mathbf{y}'_a, \mathbf{x}'_a)$, and the matrix T is defined as follows:

$$T = \begin{bmatrix} \alpha_1 I & 0 \\ \alpha_2 I & 0 \\ \vdots & \vdots \\ \alpha_K I & 0 \\ 0 & \beta_1 I \\ \vdots & \vdots \\ 0 & \beta_2 I \\ 0 & \beta_K I \end{bmatrix}.$$

Notice, furthermore, that condition (7) does not imply a priori knowledge of the aggregate solution. It simply states that, for achieving consistent aggregation, the micro and macro solutions must be related in the manner indicated above. Condition (6) relates the micro and macro slack vectors.

Perfect Aggregation under Constrained Consistency

Any set of microvariables ($\mathbf{q}$, $\mathbf{z}$, $\mathbf{w}$) which satisfies (5), (6), and (7), also must satisfy the following relations:

$$\mathbf{q}_a = T'\mathbf{q}, \tag{8}$$

$$\mathbf{w}_a = T'\mathbf{w}, \tag{9}$$

$$\mathbf{z}_a = U'\mathbf{z}. \tag{10}$$

Again, this specification of aggregation is the same as that of Day, Guccione and Oguchi, and others. The only difference with those treatments is that we have adopted matrix notation throughout. As indicated by these authors, the specification of exact aggregation chosen by them imposes stringent restrictions upon the structure of the micro and macro systems. For example, in their case, all the technology matrices in the microsystem must be identical and equal to the technology matrix in the macrosystem. This requirement is not necessary in this discussion.

All the same, the specification of perfect aggregation and disaggregation stated above implies definite restrictions for the structure of problems (1)–(2) and (3)–(4). Such restrictions are made explicit by the following aggregation:

THEOREM: *The necessary and sufficient conditions for perfect aggregation under constrained consistency are*

$$MT = UM_a, \tag{11}$$

$$T'U = I, \tag{12}$$

where I is an identity matrix.

Proof: (*Necessity*.) Premultiplying (3) by U and substituting (7) into (1), we obtain

$$(13) \qquad -U\mathbf{q}_a = -U\mathbf{w}_a + UM_a\mathbf{z}_a,$$

$$(14) \qquad -\mathbf{q} = -\mathbf{w} + MT\mathbf{z}_a.$$

Hence, in view of (5) and (6),

$$(15) \qquad MT\mathbf{z}_a = UM_a\mathbf{z}_a.$$

Since $\mathbf{q}_a$ can be chosen arbitrarily, let $\mathbf{q}_a = -M_{a,i}$, where $M_{a,i}$ is the ith column of M_a. Then, $\mathbf{z}_a = \mathbf{e}_i$ is a complementary solution to the aggregate system (3), where $\mathbf{e}_i$ is the ith column of I. It follows that (15) must hold for $\mathbf{z}_a = \mathbf{e}_i$. When this operation is repeated for each i, $i = 1, \ldots, s$, (15) yields (11). Condition (12) is obtained easily by premultiplying (5) by T', comparing the result to (8) and recalling that $\mathbf{q}_a$ is arbitrary.

(*Sufficiency*.) If (11) holds, any complementary solution ($\mathbf{z}$, $\mathbf{w}$) of the micro-LC problem (1) and (2) which also satisfies (5), (6), and (7), produces a complementary solution ($\mathbf{z}_a$, $\mathbf{w}_a$) for the aggregate problem (3) and (4). In fact, $\mathbf{w}_a = T'\mathbf{w} \geq \mathbf{0}$, and $\mathbf{z}_a = U'\mathbf{z} \geq \mathbf{0}$, since T and U are nonnegative matrices. Furthermore,

$$(16) \qquad \mathbf{z}'_a M'_a = \mathbf{z}' UM'_a = \mathbf{z}'M'T = (-\mathbf{q}' + \mathbf{w}')T = -\mathbf{q}'_a + \mathbf{w}'_a,$$

which establishes the feasibility of $\mathbf{z}_a$ and $\mathbf{w}_a$. To show that they constitute also a complementary solution, it is sufficient to recall that ($\mathbf{z}$, $\mathbf{w}$) is (by assumption) a complementary solution, and

$$(17) \qquad \mathbf{z}'_a\mathbf{w}_a = \mathbf{z}'UT'\mathbf{w} = \mathbf{z}'\mathbf{w} = \mathbf{0},$$

because $UT'\mathbf{w} = U\mathbf{w}_a = \mathbf{w}$, according to (6).

A few comments are in order. The condition that $T'U = I$, when both T and U are assumed to be nonnegative matrices, imposes stringent requirements upon their structure as well as upon that of the LC problems to be aggregated. In fact, each row of the matrix T must contain one and only one nonzero (positive) element in the same position as the corresponding nonzero element of each row of the matrix U.

These are essentially the restrictions imposed by Day and Guccione and Oguchi, upon their aggregation operators U and T which, in turn, require the micro and macro technology matrices to be identical. Their conclusion seems to be that for gaining in interpretability of the aggregation results the microproblems to be aggregated must exhibit proportionality of all components. This view of the aggregation possibilities of mathematical programming models is too pessimistic and can be improved within the present framework.

Under constrained consistency, in fact, there exist multiple sets of aggregation matrices. Indeed, any other matrix U^*, such that $MT = U^*M_a$ and $T'U^* = I$, can replace the matrix U as an aggregation operator. It is important to point out that also matrices with negative elements, properly qualified, can be admitted as perfect aggregation operators. The qualification can be established as follows: any matrix H, defined as $H = U - U^*$ and such that $T'H = 0$, establishes a variability limit for any aggregation matrix U^* from the matrix U, because only in this case we have that $T'H = T'U - T'U^* = 0$, or $T'U = T'U^* = I$. The matrix U^* is not unique and, in general, it contains some negative elements. Still, the relation $\mathbf{z}_a = U^{*\prime}\mathbf{z}$ remains nonnegative since $\mathbf{z}_a = (U' - H')\mathbf{z} = U'\mathbf{z} - \mathbf{H}'z$ and $\mathbf{H}'z = \mathbf{0}$ because, using (7) and $T'H = 0$, we have $H'\mathbf{z} = H'T\mathbf{z}_a = \mathbf{0}$. The relaxation of the restrictions upon the structure of the aggregation operator U is important because in this way it admits to perfect aggregation problems with nonproportional technologies. It is important also to point out immediately that the interpretability of the aggregate components of the problem is not necessarily lost with the introduction of matrices of the U^* type.

Perfect Aggregation of Quadratic and Linear Programs

The most general form of quadratic programming is the symmetric structure discussed by Cottle, Paris, and defined as follows:

$$(18) \qquad \textit{Primal} \max g = \mathbf{c}'\mathbf{x} - \mathbf{x}'Q\mathbf{x} - \mathbf{y}'E\mathbf{y}, \quad \text{subject to } A\mathbf{x} - 2E\mathbf{y} \leq \mathbf{b}, \quad \text{and } \mathbf{x} \geq \mathbf{0}, \mathbf{y} \geq \mathbf{0};$$

$$(19) \qquad \textit{Dual} \min p = \mathbf{b}'\mathbf{y} + \mathbf{x}'Q\mathbf{x} + \mathbf{y}'E\mathbf{y}, \quad \text{subject to } A'\mathbf{y} + 2Q\mathbf{x} \geq \mathbf{c}, \quad \text{and } \mathbf{x} \geq \mathbf{0}, \mathbf{y} \geq \mathbf{0},$$

where Q and E are known positive semidefinite matrices of order n and m, respectively, while $\mathbf{c}$ and $\mathbf{b}$ are given vectors of coefficients which admit parametric variations. The symmetric QP problem (18) and (19) may be restated as a linear complementarity problem (1) and (2) via the following correspondence:

$$\mathbf{q} = \begin{bmatrix} \mathbf{b} \\ -\mathbf{c} \end{bmatrix}, \ \mathbf{z} = \begin{bmatrix} \mathbf{y} \\ \mathbf{x} \end{bmatrix},$$

$$M = \begin{bmatrix} 2E & -A \\ A' & 2Q \end{bmatrix}, \ \mathbf{w} = \begin{bmatrix} \mathbf{v} \\ \mathbf{u} \end{bmatrix},$$

where $\mathbf{v}$ and $\mathbf{u}$ are slack vectors associated with the primal and dual constraints of (18) and (19), respectively.

The aggregation matrices T and U are specified as block-diagonal matrices:

$$T = \begin{bmatrix} W & 0 \\ 0 & D \end{bmatrix},$$

$$U = \begin{bmatrix} P & 0 \\ 0 & G \end{bmatrix},$$

with submatrices W and P of dimensions $m \times h$, while D and G are of dimensions $n \times k$, $h < m$, $k < n$. In explicit form, the aggregation condition (11) becomes

(20) $$EW = PE_a,$$

(21) $$A'W = GA'_a,$$

(22) $$AD = PA_a, \text{ and}$$

(23) $$QD = GQ_a,$$

where E_a and Q_a are positive semidefinite matrices of order h and k, respectively, defining the aggregate, symmetric, quadratic programming problem. The matrix A_a represents the aggregate technology.

The aggregation condition (12) corresponds to

(24) $$W'P = I_h,$$

(25) $$D'G = I_k,$$

where I_h and I_k are identity matrices of order h and k, respectively. Notice that if $E = 0$ and $E_a = 0$, conditions (21), (22), and (23) represent the necessary and sufficient conditions for aggregating the traditional asymmetric quadratic programming problem. If also $Q = 0$ and $Q_a = 0$, relations (21) and (22) constitute the conditions for perfect aggregation of linear programming models.

Finally, notice that premultiplying (11) by T', one obtains

(26) $$T'MT = M_a,$$

which defines the relationship between the micro and the aggregate matrices of the two LC problems. In terms of the symmetric quadratic programming model (18) and (19), relation (26) becomes

(27) $$W'EW = E_a,$$

(28) $$D'A'W = A'_a,$$

(29) $$W'AD = A_a,$$

(30) $$D'QD = Q_a.$$

We wish to reemphasize that the mathematical programming micro and macro structures specified in this section include, as special cases, the formulations of the aggregation problem stated by Day, Lee, Miller, Guccione and Oguchi, Oguchi and Guccione, and others. To see this, it is sufficient to adopt the structure of the block-diagonal matrix A previously defined. It is obvious that when one seeks to aggregate quadratic programming models of K individual firms, the matrices Q and E also exhibit a block-diagonal structure.

An Illustration of Perfect Aggregation and Disaggregation of QP Models

An asymmetric quadratic programming problem was chosen to illustrate the consistent aggregation procedures. Tables 1 and 2 contain all the relevant information. We hypothesize a block-diagonal matrix of the microtechnology A, with unequal submatrices on the diagonal. The submatrices A_1 and A_2 represent the technologies of two firms of unequal dimensions. Each firm produces a homogenous commodity by means of its first activity; and therefore its quantities can be aggregated in terms of their original units. This assumption is reflected in the components of the matrix G which are all ones and zeros. The first resource (land) of each firm is imperfectly homogenous. Yet, it is desirable to consolidate them into a unique class of resources. To accomplish this objective, it is necessary to transform the original measures of the resources into efficiency units. This is the reason why the nonzero weights of the W matrix are not unitary. The matrices Q_1 and Q_2 are positive definite and specify the quadratic forms in the objective functions of the two firms. They also form the blocks in the block-diagonal matrix Q.

The information in tables 1 and 2 can easily be used to form the micro and the macro quadratic programming problems and to verify that all their components and solutions satisfy the assumptions and the conditions of the aggregation theorem.

This example also offers an illustration of

Table 1. Aggregation of Quadratic Programs under Constrained Consistency

Set Number		Aggregate		Firm 1	Firm 2	
	A_k, $k = a,1,2$	2	3/2	49/36	49/10	12/5
		3	4	—	21/5	16/5
	Q_k, $k = a,1,2$	337/2800	3/40	359/3600	5/16	21/160
		3/40	1/10	—	21/160	1/10
1	$\mathbf{c}_k$, $k = a,1,2$	2	31/12	1/24	111/32	31/12
	$\mathbf{b}_k$, $k = a,1,2$	5	9	13/12	254/35	36/5
	$\mathbf{x}_k$, $k = a,1,2$	.4875	1.8844	.2089	.2787	1.8842
	$\mathbf{y}_k$, $k = a,1,2$	0.0000	.5333	.0000	.0000	.6667
	$\mathbf{g}_k = \mathbf{p}_k$, $k = a,1,2$	5.3215		.0044	5.3171	
2	$\mathbf{c}_k$, $k = a,1,2$	31/9	31/12	217/216	1519/288	31/12
	$\mathbf{b}_k$, $k = a,1,2$	7	12	5/3	352/35	48/5
	$\mathbf{x}_k$, $k = a,1,2$	2.8571	.8571	1.2245	1.6326	.8571
	$\mathbf{y}_k$, $k = a,1,2$	1.3036	.0070	.5587	.8147	.0087
	$\mathbf{g}_k = \mathbf{p}_k$, $k = a,1,2$	10.6322		1.0806	9.5516	
3	$\mathbf{c}_k$, $k = a,1,2$	2	31/12	1/24	111/32	31/12
	$\mathbf{b}_k$, $k = a,1,2$	607/28	55	59/84	1676/49	44
	$\mathbf{x}_k$, $k = a,1,2$	.4866	12.5530	.2089	.2783	12.5519
	$\mathbf{y}_k$, $k = a,1,2$	.0000	.0000	.0000	.0000	.0000
	$\mathbf{g}_k = \mathbf{p}_k$, $k = a,1,2$	16.6993		.0044	16.6949	

the existence of multiple sets of aggregation operators. Such alternative matrices can perform an important role in admitting great flexibility of the microtechnologies to be aggregated. Hence, $U^* = \left[\begin{array}{c|c} S & 0 \\ \hline 0 & R \end{array}\right]$ is an alternative aggregation operator fulfilling the condition $T'U^* = I$. Table 2 contains the aggregators employed in the numerical example. Table 1 exhibits the primal and dual solutions of the micro and macro problems obtained with three different sets of $\mathbf{b}$ and $\mathbf{c}$ vectors but the same operators as in table 2. The components of these vectors were selected to represent the

Table 2. Consistent Aggregation Operators

Aggregation Operators	Firm 1		Firm 2	
W_k, $k = 1,2$	3/7	0	5/8	0
	—	—	0	5/4
D_k, $k = 1,2$	3/7	0	4/7	0
	—	—	0	1
R_k, $k = 1,2$	2/3	−1/2	5/4	3/8
	—	—	0	1
S_k, $k = 1,2$	2/3	−1/4	8/7	6/35
	—	—	0	4/5
G_k, $k = 1,2$	1	0	1	0
	—	—	0	1
P_k, $k = 1,2$	1344/1801	0	1960/1801	0
	—	—	0	4/5

following cases: (a) boundary solution for firm 2 and interior solution for firm 1; (b) boundary solutions for both firms; (c) interior solutions for both firms. It can be verified easily that the aggregation is perfect in all three cases for both primal and dual variables. Indeed, notice that not only $\mathbf{x}_a = G'\mathbf{x}$ and $\mathbf{y}_a = P'\mathbf{y}$, but also $\mathbf{x}_a = R'\mathbf{x}$ and $\mathbf{y} = S'\mathbf{y}$, for all three numerical specifications. It should be clear that the same operators presented in table 2 can be used to perform perfect aggregation and disaggregation of all the micro and macro solutions in this numerical example obtained under a choice of the $\mathbf{b}$ and $\mathbf{c}$ vectors which satisfies relation (5). Hence, once a set of aggregation operators has been computed relative to some microtechnology, it can be used without need of revision in the consistent aggregation and disaggregation of the models, for an infinite number of $\mathbf{c}$ and $\mathbf{b}$ vectors satisfying (5).

The issue of interpretability of the aggregation results under the general specification of constrained consistency deserves some comments. As demonstrated by the numerical example, no problem arises in the interpretation of the macrosolutions $\mathbf{x}_a$ and $\mathbf{y}_a$. From the relation $\mathbf{x}_a = G'\mathbf{x}$, with the aggregation operator $\mathbf{G}$ specified as in table 2, each component of the vector $\mathbf{x}_a$ represents corresponding microvariables and possesses their same measurement units. Similarly, the dual macrovariables $\mathbf{y}_a$ satisfy the relation $\mathbf{y}_a = P'\mathbf{y}$,

with P as given in table 2, indicating that, also in this case, each macro dual variable represents corresponding micro dual variables. Of course, the nonzero elements of the P matrix are in general not unitary since they must aggregate "shadow prices."

The interpretability of the macrotechnology A_a, and of the matrix Q_a of macro demand slopes is also perfectly natural and meaningful. Notice that, from relation (28) or (29), the macrotechnology A_a is defined as $A_a = W'AD$. With the structure of the aggregation operators W and D given in table 2, it follows that each macro activity is defined in terms of the corresponding micro activities. In other words, if the first activity of each of the two firms represents tomatoes, the technical coefficients of the first macro activity are defined exclusively in terms of the land/tomato micro coefficients. The use of nonunitary weights of the aggregation matrixes W and D simply means that such macro coefficients are measured in efficiency units, rather than the natural units of their micro counterparts. But, as specified in the statement of the numerical example, the efficiency units were necessary to produce a unique measure of resources which were assumed to be imperfectly homogenous. Analogously, since $Q_a = D'QD$, the coefficients of the aggregate matrix Q_a are defined exclusively in terms of corresponding microcomponents and their interpretation is, thus, straightforward.

Finally, observe that under the aggregation specification used, no problem arises in the perfect aggregation of dual variables in quadratic programming models. This is in contrast with proposition 2 of Oguchi and Guccione. A careful examination of the assumptions and restrictions involved in the two specifications indicates that the source of discrepancy lies with the way the aggregate matrix Q_a (C_o in Oguchi and Guccione's paper) is related to the corresponding micro quadratic form matrix Q. Oguchi and Guccione chose to define a priori the macro quadratic form matrix Q_a as $Q_a = \Sigma_k \alpha_k Q_k$, $\alpha_k \geq 0$, $\Sigma_k \alpha_k = 1$, $k = 1, \ldots, K$. In this paper, however, the relation between these micro and macro matrices was a result (not an a priori assumption) of the analysis. Notice that from condition (30), $Q_a = D'QD$. It can be shown, therefore, that if the definition of the macro quadratic form in Oguchi and Guccione's paper were given as $Q_a = \Sigma_k \alpha_k^2 Q_k$, exact aggregation of the dual variables would be possible. To illustrate this point according to the stringent assumptions of Oguchi and Guccione, suppose there are only two firms with microtechnologies equal to each other's and to the aggregate technology, $A_1 = A_2 = A_a$; the micro quadratic form matrices also are equal, $Q_1 = Q_2 = Q^*$ and the aggregate quadratic form is defined as $Q_a = \Sigma_k \alpha_k^2 Q^*$, where $\alpha_1 = 1/4$ and $\alpha_2 = 3/4$. The microresource constraints $\mathbf{b}_1$ and $\mathbf{b}_2$ are proportional to the aggregate $\mathbf{b}_a$, and their sum corresponds to $\mathbf{b}_a = \mathbf{b}_1 + \mathbf{b}_2$. The vectors $\mathbf{c}_1$ and $\mathbf{c}_2$ in the micro-objective functions are identical and are aggregated with weights 1/4 and 3/4, respectively, to form the vector $\mathbf{c}_a$ in the macro-objective function; that is, $\mathbf{c}_a = \mathbf{c}_1/4 + 3\mathbf{c}_2/4$. Let

$$A_1 = A_2 = A_a = \begin{bmatrix} 2 & 3/2 \\ 3 & 4 \end{bmatrix},$$

$$Q_1 = Q_2 = \begin{bmatrix} 337/1750 & 3/25 \\ 3/25 & 4/25 \end{bmatrix}$$

$$\mathbf{c}'_1 = \mathbf{c}'_2 = [31/9 \quad 31/12],$$

$$\mathbf{b}'_1 = [7/4 \quad 3],\ \mathbf{b}'_2 = [21/4 \quad 9],$$

then, $Q_a = (1/16)Q_1 + (9/16)Q_2$

$$= \begin{bmatrix} 337/2800 & 3/40 \\ 3/40 & 1/10 \end{bmatrix}, \text{ and}$$

$$\mathbf{c}'_a = (1/4)\mathbf{c}'_1 + (3/4)\mathbf{c}'_2 = [31/9 \quad 31/12],$$
$$\mathbf{b}'_a = \mathbf{b}'_1 + \mathbf{b}'_2 = [7 \quad 12].$$

It can be verified that the solution of the aggregation problem is exact on both the primal and dual sides. In fact,

$$\mathbf{x}'_a = [20/7 \quad 6/7],\ \mathbf{x}'_1 = [5/7 \quad 3/14],$$
$$\mathbf{x}'_2 = [15/7 \quad 9/14],$$
$$\mathbf{y}'_a = [1.303563 \quad .006997],$$
$$\mathbf{y}'_1 = [1.554759 \quad .002799],$$
$$\mathbf{y}'_2 = [1.219832 \quad .008396].$$

Clearly, $\mathbf{x}_a = \mathbf{x}_1 + \mathbf{x}_2$ and $\mathbf{y}_a = (1/4)\mathbf{y}_1 + (3/4)\mathbf{y}_2$.

In summary: under the aggregation specification formulated in this paper, one obtains perfect aggregation of the primal and dual variables as well as of the primal and dual objective functions; whereas, with that of Oguchi and Guccione, the aggregation is not possible even for the primal micro-objective functions which do not involve dual variables.

Finally, when dealing with the aggregation of symmetric quadratic programming models, Oguchi and Guccione's proposition 2 leads to the following contradictory conclusion: if the dual variables in QP models cannot be perfectly

aggregated, it follows that in symmetric QP models the primal variables as well cannot be aggregated. This is so because in such models the dual variables enter also the primal constraints.

The conclusion seems inescapable: In aggregating QP models, the quadratic form matrix Q_a ought to be defined in terms of the square of the weights used to aggregate the microvectors $\mathbf{c}_k$.

Conclusions

We have shown that it is possible to achieve perfect aggregation for linear complementarity problems of considerable generality. The aggregation specification, however, must be qualified by the notion of constrained consistency. Although restricting the domain of the microvariables to be aggregated, the consequences of constrained consistency can be mitigated by the use of alternative sets of aggregation operators, one for the variables and one for the technologies.

The aggregation problem, it was seen, can be tackled in at least two ways. The first one is represented by the traditional approach of specifying all aggregation operators to be nonnegative with 0, 1 elements. As argued by Day, Guccione and Oguchi, and others, aggregation using these simple matrices requires the identity of the microtechnologies, and the proportionality of the resource and net revenue microvectors.

The second approach, presented here, is more flexible. It admits the perfect aggregation of microsystems without requiring the identity of the corresponding firms' technologies and the proportionality of resource and revenue microvectors.

In both cases, it is important to underline, the interpretation of the components of the aggregate structure is feasible and direct. In the second, more general, approach, aggregate components are likely to be measured and interpreted in efficiency units.

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References

Cottle, R. W. "Symmetric Dual Quadratic Programs." *Quart. Applied Math.* 21(1963):237–42.

Day, R. H. "On Aggregating Linear Programming Models of Production." *J. Farm Econ.* 45(1963):797–813.

Guccione, A., and N. Oguchi. "A Note on the Necessary Conditions for Exact Aggregation of Linear Programming Models." *Math. Programming* 12(1977):133–35.

Ijiri, Y. "Fundamental Queries in Aggregation Theory." *J. Amer. Statist. Assoc.* 66(1971):766–82.

Lee, J. E. "Exact Aggregation. A Discussion of Miller's Theorem." *Agr. Econ. Res.* 18(1966):58–61.

Lemke, C. E. "Equilibrium Points of Bimatrix Games." *J. Soc. Indust. Applied Math.* 12(1964):413–23.

———. "On Complementarity Pivot Theory." *Mathematics of the Decision Sciences*, ed. G. B. Dantzig and A. F. Veinott, Jr., Pt. 1, pp. 95–114. Providence, R.I.: American Mathematical Society, 1968.

Miller, T. A. "Sufficient Conditions for Exact Aggregation in Linear Programming Models." *Agr. Econ. Res.* 18(1966):52–57.

Oguchi, N., and A. Guccione. "Perfect Aggregation Conditions for Quadratic Programming Models." *Amer. J. Agr. Econ.* 61(1979):558–60.

Paris, Q. "Revenue and Cost Uncertainty, Generalized Mean-Variance, and the Linear Complementarity Problem." *Amer. J. Agr. Econ.* 61(1979):268–75.

Paris, Q., and G. C. Rausser. "Sufficient Conditions for Aggregation of Linear Programming Models." *Amer. J. Agr. Econ.* 55(1973):659–66.

American Indian Farm Planning: An Analytical Approach to Tribal Decision Making

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A multiyear linear programming model is used to assist an American Indian tribe develop agricultural plans for their tribal farm. Five-year crop, livestock, and investment plans are generated consistent with the tribal resource base, goals, and decision-making structure. The model has influenced the tribal farm decision-making process and provided the primary farming guide for 1979 and 1980. Frequent communication with the tribe was crucial in developing the model. Adequate updating procedures will be important in future farm planning.

Key words: American Indian, decision-making structure, farm, linear programming.

Many American Indian reservations are located in areas where agriculture is the primary source of income. For most Indian tribes on these reservations, agricultural land and labor are their primary resources. Few tribes, however, have been able to develop those resources to the point where agriculture contributes significantly to their economic and social well-being. Numerous hypotheses have been advanced to explain why Indian agricultural development has proceeded so slowly. Fractionated heirship lands, federal policies which have diminished the incentive to work, racial discrimination, certain aspects of Indian culture, a lack of formal education, and the absence of sufficient capital to make investments have all been mentioned as deterrents to agricultural development (Fitch, Dorner, Sorkin, Levitan and Johnston). Trosper has pointed out that Indian ranchers on the Northern Cheyenne Reservation own a small proportion of the land they graze and that this apparently has hindered access to capital.

In the 1970s there has been increased interest among Indian tribes in accelerating agricultural development. A few have established tribally owned farms. The Sisseton-Wahpeton Sioux Indians on the Lake Traverse Reservation in Northeastern South Dakota have established a tribal farming operation and sought planning assistance for that enterprise. This article describes the planning approach used to evaluate crop, livestock, and investment alternatives for the tribal farm. It begins with a description of the tribal resource base, agricultural goals, and decision-making structure. The planning model employed to reflect these factors is then described, followed by the resulting plans and a discussion of how closely they were followed. Procedures for updating the plans are presented and, finally, conclusions are drawn about the potential usefulness of this approach to other tribes.

Background

Approximately 3,900 members of the Sisseton-Wahpeton Sioux Tribe (SWST) reside on the Lake Traverse Reservation, representing 15% of the total reservation population. While agriculture is the primary industry in the area, less than 10% of the 1,100 Indian labor force is employed in agriculture. Per capita income is about $1,000 for Indians liv-

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ing on the reservation and can be traced partly to the high unemployment rate. The major employer of Indians in the area is the tribe itself, through the various government programs for which it has contracted. Both the lack of job opportunities and the low education level of tribal members contribute to this situation. The education level of the Indians on the reservation has been rising, but approximately one-fifth of the Indians twenty-five years and older have not completed the eighth grade, compared to one-eighth of the non-Indian population.

The total land area of the reservation is 910,779 acres, of which approximately 91,000 acres are presently owned by individual Indians, 15,000 by the tribe itself, and the remaining 804,000 (88.3% of the total) by non-Indians. Usage of the Indian-held land is approximately 35% cropland, 56% pasture, and the remainder nonagriculture. These lands are spread out over the reservation in a checkerboard pattern. Most tribal members own small parts of several tracts of land and the vast majority of the tracts have multiple ownership by the heirs of the original allottee.[1] Each Indian enrolled in SWST has interest in an average of eight tracts and each tract of land has, on the average, thirteen Indian owners (U.S. Department of Interior, BIA). Most of the land is leased to non-Indian farm and ranch operators, although Indian operators lease some land.

A variety of small grains and row crops can be raised on the land owned by the tribe. The area has an average annual precipitation around 21 inches and a growing season of 135–140 days. There is little potential for irrigation from lakes and streams but some potential from groundwater sources. The most common livestock activity is a small cow-calf operation.

The Sisseton Reservation is an underdeveloped enclave within a more developed economy. Consequently, improved technologies specific to the area already exist. Part of what is needed is a mechanism to diffuse this knowledge in a manner consistent with the tribe's land, capital, and human endowment as well as the socioeconomic environment.

The Tribal Farm and Decision Making

The SWST began a land consolidation program in 1973 by purchasing from individual Indians tracts of land that had become fractionalized over time. Capital for these land purchases came from $4.25 million in Farmers Home Administration (FmHA) loans secured with money from land claim settlements with the federal government. The tribal farm was established on a small part of these lands in 1975 with financial assistance from the Economic Development Administration and technical assistance from the extension service. The tribal approach to farming was emphasized instead of individual ownership and management. Certain sources of capital were available to tribally controlled enterprises from both government and commercial sources that were not available to individual tribe members. Tribal leaders felt that cultural and managerial problems would be minimized by adopting a centralized decision-making structure.

After the first full year of farming (1976), tribal leaders requested assistance in developing short- and longer-range farm plans. They did so because they perceived that some of the problems experienced the first year resulted from a lack of an integrated plan. They wanted projections on the possible size and profitability of the farm after five years, analysis of the feasibility of irrigation, and information concerning the most profitable size of cattle operation, etc. Furthermore, they expressed a concern about the riskiness of activities because of outstanding FmHA loans on the tribal farm land.

One of the authors worked with the tribal leadership to develop a planning procedure and plans consistent with their decision-making structure and their resource endowments. At the beginning of the project, three months were spent in the tribal planning office collecting information and exchanging ideas. This contact was important in establishing channels of communication and gaining credibility. During the remainder of the two-year project, approximately twenty-five visits were made to the reservation to discuss ideas and results with the tribe.

[1] The allotment of lands to individual Indians occurred on the vast majority of Indian reservations following the passage of the Dawes Act in 1887. One of the provisions of the law provided for the federal government to hold land in trust for all heirs of deceased landowners rather than assigning it to one person. By the time Indians were allowed to sell their lands, an heirship problem which still plagues many reservations today was well-established. Some forty-acre plots now have as many as 150 heirs. Once lands were allotted to individual Indians on the Lake Traverse Reservation, non-Indians were allowed to homestead the rest, which placed most of it in the hands of non-Indians.

Discussions were held with tribal leaders and the planning director to help specify planning objectives. A written statement of objectives for the tribal farm(s) was provided by the tribe. It expressed a desire that the tribal farm(s) would (*a*) help strengthen the tribe's economic base in the event that the federal government continues to withdraw or terminates financial support of Indian tribes, (*b*) provide income, employment, and training opportunities for individual tribal members, and (*c*) generate revenue to help the tribe maintain control over its land base. The Sisseton-Wahpeton Sioux hoped that the tribal farm would provide examples for individual tribe members. They also feel the need to establish a record of success in an economic endeavor to place themselves on a more equal footing with the non-Indian community. They see tribal farming as only one part of a larger development program, but one which will facilitate expansion into other activities.[2] Objectives for the tribal farm were discussed many times during the course of the project. The issue of short-term versus long-term objectives was raised. Tribal leaders expressed a willingness to forego withdrawal of any profits in the first years to facilitate farm expansion. There is not complete agreement on this, however, and it is still a topic of debate within the tribe. A concern also has been expressed that the plans not be too risky because a substantial loss by the tribal farm might result in pressure to abolish it without giving it an adequate chance.

The planning model for the farm was developed to reflect and obtain insights into the implications of these objectives. The model on which plans were to be based also needed to take into consideration the tribal decision-making structure. There are three levels of decision-making authority which are pyramidal in structure. The decisions at the first level focus on plans and policies whose implementation at lower levels allows for some discretionary authority.

Decision-making authority at the first level is held by the tribal council, but currently most of the decision-making responsibility at this level is delegated to the tribal chairman. The chairman will sometimes confer with the tribal secretary, treasurer, or the full council before making certain decisions. He has information provided by a planning staff and tribal accounting office, such as the lease status of tribally owned land tracks, cash in the tribal farm account, and the status of federal grant proposals. The chairman also uses information provided by sources outside the tribe including the extension service and the computer planning model.

The decision maker at the second level is the farm manager. He interacts with and implements the decisions of the tribal chairman making the necessary assignments of labor, machinery, etc. The farm manager is constrained by his ability and experience, weather, and the quality of the labor force. He, in turn, must interact with those at the third decision level, the farm workers. While the workers' authority is more circumscribed, their efficiency influences the economic performance of the tribal farm.

The planning model, described in this paper, gives and receives information to and from the first and second decision levels as well as the planning staff and accounting office. The usefulness of an analytical planning model lies in the ability to search efficiently among many alternatives for the best strategy for achieving tribal objectives, subject to policy, risk, and physical constraints. It also enables tribal leaders to assess the effects on their objectives of varying those constraints. The model should reflect decision variables and constraints at the highest level as well as certain constraints at lower levels. Consequently, information was collected on soils, climate, labor availability and skills, crop yields, input and output prices, water availability, land and machinery ownership, borrowing sources and limits, etc. Tribal lands were classified and mapped into capability classes and the lease status of these lands was reviewed.

The model which was constructed reflects the lack of experience of both the farm manager and the rest of the work force through limits on the types of farming activities permitted.[3] At the same time, the climate, topography, and location with respect to markets will enable a wider range of possible crop and livestock activities to be included in the future. In addition, the model generates plans which consider not only the complementarities between crop and livestock enterprises but also the level of risk to the tribe.

[2] Profits generated by tribal activities on Indian-owned land are nontaxable by federal, state, and local governments.

[3] For example, irrigated alfalfa and corn are permitted during the first five years but not irrigated vegetables. Alfalfa and corn are easier crops to irrigate than vegetables for an inexperienced irrigator.

Methodology

The basic analytical technique used in the planning process is a multiyear linear programming model (MLP). Its primary objective is to determine a set and level of activities for the tribal farm(s) which maximize ending net worth subject to risk constraints and to limits placed on the enterprises by the availability of land, labor, machinery, and credit. Maximization of ending net worth was chosen as the initial objective function because the tribe expressed a willingness to sacrifice short-term consumption to facilitate farm expansion. An alternative objective of maximizing the sum of annual consumption plus ending net worth discounted at 9% also was used in the analysis and the results presented to the tribal chairman for comparison.

Linear programming was used rather than quadratic because of the computational cost advantage. The model contains five one-year time periods with 896 columns and 696 rows.[4] Five-year planning prices were based on outlook projections made by agricultural economists at the University of Minnesota, adjusted to reflect the expected difference between the local and the Minneapolis price. The model's general specification is

Primal		*Dual*
Maximize $\mathbf{C}'\mathbf{X} - \lambda\mathbf{d}$,	=	minimize $\mathbf{B}'\mathbf{Y}$,
subject to $A\mathbf{X} \leq \mathbf{B}$,		subject to $A'Y$
$D\mathbf{X} + I\mathbf{d} \geq 0$,		$+ D'Q \geq \mathbf{C}$,
		$IQ \leq -\lambda$,
and $\mathbf{X}, \mathbf{d} \geq 0$,		and $\mathbf{Y}, Q \geq 0$,

where $\mathbf{C}$ is a vector of objective function coefficients, $\mathbf{X}$ is the activity vector, A is a matrix of technical input-output coefficients, $\mathbf{B}$ is a vector of resource availabilities, and D is a gross-margin deviation matrix (see Hazell, Brink and McCarl). The vector $\mathbf{d}$ represents yearly total negative deviations summed over all risky activities. I is an identity matrix, λ is a risk-aversion coefficient, $\mathbf{Y}$ is a vector of shadow prices on nonrisk constraints, and Q is the shadow price on each risk constraint.

The activities in the model fall basically into nine classes: (*a*) crop production, (*b*) livestock production, (*c*) renting in of labor, land, and machinery, (*d*) cattle and feed purchasing, (*e*) crop and livestock selling, (*f*) machinery, storage, and building purchasing, (*g*) borrowing, (*h*) crop, livestock, and money transfers, and (*i*) risk transfers. The constraints and row transfers can be grouped into seven classes: (*a*) resource constraints, (*b*) crop transfers, (*c*) livestock transfers, (*d*) nutrient transfers, (*e*) cash flow constraints, (*f*) credit constraints, and (*g*) risk constraints.

Table 1 presents an aggregated representation of the model. Most of the activities and rows shown represent numerous activities and rows in the model. For example, crop production includes activities for ten crops in the model, with land divided into four dryland and one irrigated class. Labor requirements, cash requirements, machinery requirements, and set-aside requirements for each crop were included. Crop production is transferred in the model to selling, feeding, or storing activities. All land is assumed to be rented from the tribe by the tribal farm at the current lease rates established by the tribe. This mirrors the current situation and ensures that land which would be more profitably rented out to someone else will not be farmed by the tribe.

Various beef cattle activities designed to reflect the prevailing alternatives in the area, as well as the experience of the tribal labor force, are included in the model. They are (*a*) a cow-calf operation, (*b*) summer grazing of heifers or steers of two weight classes, (*c*) winter feeding of heifer or steer calves, (*d*) finishing heifers or steers of two weight classes during the winter, (*e*) raising replacement heifers for the cow herd, and (*f*) keeping bulls.

Cattle can be produced internally or purchased. Calves from the cow-calf alternative can be sold at weaning time, overwintered and sold, or overwintered and summer grazed. The steers can then be sold or finished over the winter and the heifers sold or enter the herd as replacements. Calves also can be purchased in the spring and summer grazed and then sold or kept and finished over the winter. The model also determines the optimal feed mix for the selected livestock activities based on dry matter, digestible protein, and total digestible nutrient requirements and supplies.

Investment alternatives for various types of

[4] The main purpose for including years beyond the first is to help the tribal leaders make decisions in the first year which are consistent with their long-term objectives and resources. If parameters such as the terminal value of assets could be appropriately specified, a single-year model would yield a solution identical to the first year of a multiyear model. The shorter the planning horizon, the more mistakes made in estimating future income streams of terminal assets will compound one another. Therefore, the effect on the first-year solution will be greater. The tribe also requested at least a five-year projection of farm size and net worth. The model has not been extended beyond five years because this would require sacrificing detail in early years in order to keep the size of the model within a manageable limit.

Table 1. Aggregated Representation of Tribal Farm Model

Rows \ Columns	Year 1											Year N															
	CP	*CS*	*FP*	*FT*	*LP*	*LS*	*RR*	*RP*	*STF*	*LTF*	*IPT*...	*CP*	*CS*	*FP*	*FT*	*LP*	*LS*	*RR*	*RP*	*STF*	*LTF*	*IPT*	*RK*	*DP*	*ET*	*R*	*RHS*
Objective Function																						C	−λd	−C	C		Max
Year 1																											
Resource constraints	A				A		−A	−A																		≤	B
Crop transfers	−1	1	−1	1							1															≤	0
Livestock transfers					±1	1					1															≤	B
Nutrient transfers				−A																						≤	0
Borrowing								A		−A																≤	0
Credit									A	A																≤	B
Cash	A	−A	A		A	−A	A	A	−A	A	1															≤	B
Year N																											
Resource constraints								−A				A				A		−A	−A							≤	B
Crop transfers											−1	−1	1	−1	1							1				≤	0
Livestock transfers											−1					±1	1					1				≤	0
Nutrient transfers															−A	A										≤	0
Borrowing																			A		−A					≤	0
Credit										A										A	A					≤	B
Cash										A	−1	A	−A	A		A	−A	A	A	−A	A	A			−A	≤	−B
Risk constraints	±A				±A							±A				±A							1			≥	0
Increase equity								A											A			A				≥	0

Definitions: *CP*, Crop Production; *CS*, Crop Selling; *FP*, Feed Purchase; *FT*, Feed Transfer; *LP*, Livestock Production; *LS*, Livestock Selling; *RR*, Resource Renting; *STF*, Short Term Financing; *LTF*, Longer Term Financing; *IPT*, Interperiod Transfers; *RK*, Risk Transfers; *DP*, Activity to Subtract Initial Cash and Depreciation of Initial Assets; *ET*, Equity Transfers; *R*, Relation; and *RHS*, Right Hand Sides.

machinery, buildings, and storage are included in the model. These activities supply hours of machinery use, animal housing capacity, and tons or bushels of storage space. The monetary value of each piece of machinery or other investment is depreciated on a straightline basis and equity is calculated at the end of the five-year plan for each item. This equity is the amount paid off minus depreciation.

To reflect tribal planning needs there are rows in the model to account for inflows and outflows of cash each month and activities to transfer it from one month to the next. Three borrowing activities are included which reflect the main sources of capital available to the tribe: (*a*) long-term borrowing for buildings and irrigation equipment from Farmers Home Administration, (*b*) intermediate-term borrowing from a bank for machinery and storage, and (*c*) short-term borrowing from a bank. Each type of borrowing has its own interest rate, down-payment requirements, payback period, and credit limit. A savings alternative is also included for each year to ensure that investments are not made which yield less than the minimum opportunity cost of their capital.

A series of risk constraints and activities are included to deal with price and yield uncertainty in the crop and livestock activities. While the tribal leaders feel the farm can absorb more risk than individually owned farms, they are concerned about the riskiness of the plans for reasons mentioned earlier. Certain yield risks can be reduced by such methods as spraying for weeds, following rotations, providing supplemental irrigation, and vaccinating animals. Certain price risks can be reduced by using mechanisms to transfer risk, such as crop insurance, hedging on the futures market, and forward-contracting for market quantities or price. The major defense against income variability due to price or yield risk, however, is to select activities with lower yield and price uncertainty and eliminate or reduce those with higher uncertainty. The risk constraints in the tribal farm model in effect do this.

The approach used in the tribal farm model is based on Hazell's mean absolute total deviation (MOTAD) formulation. The activity net revenues are assumed to follow a multivariate normal distribution so that total net revenue will tend to be normally distributed and utility can be evaluated in terms of only the first two moments of the distribution of total net revenue. Mean absolute total deviations (M) are assumed to approximate the second moment or the variance (V).[5]

The deviation matrix (D) was obtained by first calculating gross margins (price times yield minus variable cost) for each crop and livestock activity in the model for each year from 1965 to 1975. For cropping activities, this was done by multiplying the average county crop yield data by the price inflated to 1975 by the USDA Parity Index and subtracting the 1975 level of variable costs. For livestock activities, it required calculating for each class of livestock the difference between the value at the time of purchase and the value at the time of sale (inflated to 1975). The 1975 level of nonfeed variable costs and feed costs calculated for each year, inflated to 1975, were then subtracted. Once the matrix of gross margins was calculated, it was then necessary to calculate the yearly deviations from the means of those gross margins. Deviations from simple means would have been misleading because of the presence of trends and the cattle cycle. Deviations from linear trends would not pick up cyclical changes. Therefore, following Brink and McCarl, deviations from a moving average of the previous four years was chosen as the deviation from the expected gross margin. Following Hazell, only negative sums of deviations are transferred to the objective function so the model actually minimizes the total negative deviations.

The level of risk assumed in the model for each enterprise is therefore based on deviations from historical gross margins. The decision maker's subjective estimate of risk inevitably will differ from this to some degree. In fact, the level of risk of an enterprise also can vary with the skill and experience of a particular manager. The purpose of including risk in the model, however, is merely to provide the decision maker with additional information on which to select a plan. It is recognized that the solutions generated by varying the risk parameter only approximates the risk

[5] It can be shown that $M^2[\pi t/2(t-1)]$ is an unbiased estimate of the population variance where M is the mean absolute deviation of expected income, π is the mathematical constant 22/7, and t is the number of observations or yearly risk constraints in this case when total gross margin distributions are approximately normal (Hazell). Thomsen and Hazell show in a Monte-Carlo simulation study that the use of an expected income-mean absolute deviation (E-M) model generates plans similar to those generated by an expected income-variance (E-V) model. It is assumed in both approaches that the decision maker is risk-averse, so that expected income would have to be greater for him to prefer higher variance of income. This compensation must increase at an increasing rate as variance increases.

faced by the tribal farm. Nonetheless, the procedure used is easy to apply and is preferable to ignoring risk altogether, because the decision maker is still free to choose the plan which gives no weight to the risk constraints.

Validation and Generation of Plans

For purposes of validation, a one-year version of the linear programming model was constructed first and the 1977 tribal farm operation was duplicated. Refinements were made and the model was updated to produce a plan for 1978. A series of plans were generated with varying levels of profit and risk; and the tribal chairman, after a discussion with the farm manager, selected the one he preferred. The model also was run with and without irrigated cropping activities, such as corn for grain and alfalfa, to determine the effect on profits. The cropping part of the selected 1978 plan was followed fairly closely, while the livestock part was not, which led to a lower-than-planned-for profit. The information from the plan also was used to assist the tribe in presenting an irrigation project proposal to the Economic Development Administration.

The model was then extended to five years beginning with 1979. Sensitivity analysis was conducted on certain price and yield coefficients, and a series of preliminary results were discussed with the tribal chairman, tribal planners, the tribal farm manager, extension personnel, and others. Some adjustments were made, and a series of eleven plans was generated by parameterizing the risk coefficient (λ) from 0 to .5. These plans were presented to the tribal chairman, who selected the plan containing the tradeoff between profit and risk which he preferred. The values of the dual variables (shadow prices) corresponding to the land, labor, machinery, and other constraints were examined. The plans had been bounded in the first year to fit the total amount of land which the tribal farm had under lease at that time. The shadow prices on Class 1 and Class 2 land indicated it would be profitable, other things constant, to lease additional cropland. The decision was then made by the tribal chairman to include additional land, and a new set of plans was generated. The production manager—inexperienced in growing soybeans—then expressed a preference not to plant any soybeans in the first year of the plan even though it was called for under each level of risk.[6] The tribal chairman agreed and the model was rerun with soybeans forced to zero. Crop acreages were then forced to fit the fields exactly, and the result was the 1979 tribal farm plan. In summary a number of steps were undertaken, including sensitivity analysis of price and yield coefficients, risk analysis, and examination of shadow prices, and the results were discussed with the tribal leaders before arriving at a plan suitable to the tribe.[7]

Results

The five-year plan developed for the tribe includes barley, spring wheat, soybeans, sunflowers, and alfalfa as the major dryland crops and corn for grain and alfalfa as the major irrigated crops. Total acreage in the tribal farms increases 1,000 acres to about 3,000 acres by 1983, of which 2,000 acres would be crops or improved pasture and 1,000 acres in native pasture. Each class of land has a corresponding constraint and shadow price for each year. The marginal value of an acre of Class 1 land in 1979, for example, is \$42.27. If an acre of Class 1 land were removed, ending net worth would decrease by \$42. This does not mean, however, that the tribal farm can afford to pay a lease rate of \$42 for that last acre of Class 1 land in 1979, because a dollar spent in 1979 is not worth the same as a dollar spent at the end of the planning horizon. The shadow price of an extra dollar in the first four months of 1979 is \$1.62. This represents the value of an additional dollar during that time compounded to the fifth year. Therefore, a dollar spent on land or any other resource in early 1979 has an opportunity cost of \$1.62. The amount that the tribal farm can afford to pay for that last acre of land is \$42.27 divided by \$1.62 = \$26.00. This latter figure would equal the lease rate if the renting in of land were not constrained in 1979.

[6] Risk was reduced when acreage of flax, soybeans, and corn acreage declined and when acreage of barley and sunflowers increased. A reduction of summer grazing of calves reduced risk slightly as did an increase in overwintering of calves.

[7] The close examination of shadow prices on constraints and nonselected activities was especially important. Schurle and Erven, for example, warn that near-optimal solutions can be substantially different from those on the efficiency frontier. Examination of shadow prices tells one a great deal about the profitability of near-optimal solutions at each level of risk. As an example, for the medium-risk plan, the forcing in of summer grazing of yearlings in years 1–4 or additional acres of corn for grain in years 2–4 would cause a small reduction in profit. The model also provides a range over which the shadow prices hold. It should also be noted that a model such as the one presented here, with a very large number of constraints, is less likely to have radically different plans for near-optimal solutions than a model with fewer constraints.

The major livestock activities selected are summer grazing of steer calves and finishing of yearlings in a farm feedlot over the winter. Expansion of the cow herd was not recommended. At tribal request, however, the model was forced to maintain a small cow herd. Calves from this herd will be fed over the winter (backgrounded). Fifteen buffalo were also forced into the solution at tribal request and the shadow price on this varied from $145 to $176 per head. This foregone income was discussed with the tribal chairman who then discussed it with the tribal council. They felt that the nonmonetary benefits would exceed the cost.

Because the tribe already owns a fairly complete and new complement of machinery, the model suggested very few major machinery investments. However, capital is one of the factors constraining tribal farm expansion. Short-term, intermediate-term, and long-term borrowing will be required for cattle purchases, machinery purchases, and the feedlot construction. Credit limits were binding in the second, third, and fourth years. A labor force of two people was required during the winter and three to four people during the remainder of the year.

The increase in ending net worth over the five years is projected to be $62,000. Operating capital increases from an initial $60,000 to $200,000, and the value of more durable assets declines by $78,000. There are two major reasons why investments in new assets are not made as rapidly as the existing stock depreciates. First, machinery depreciation is assumed to occur on a straight-line basis over ten years, while the service flow is assumed to remain constant for ten years and then fall to zero. Second, there is some overcapacity for certain types of machinery throughout the five-year planning period.

The alternative objective function of maximizing the present value of consumption plus ending net worth also was tested. An annual discount rate of 9% was used and the model was forced to withdraw $5,000 plus 10% of the year-end cash annually.[8] The resulting return to the tribe was $16,664 less than when ending net worth was maximized.[9] This resulted primarily from having less cash to reinvest each year. The plan contained similar activities, but they came in at different levels. Although tribal objectives over the next five years suggest maximizing ending net worth, in the longer run the alternative objective function would appear to best fit their objective of providing income to the tribe.

One can make some comparisons between the first year (1979) of the plan and what has occurred on the tribal farm. It must be recognized that any plan generated is only an initial guide and adjustments must be made to it as events occur during the course of the planning period. At planting time the planned irrigation system still was not in place and this forced some changes. One 80-acre tract was not put in the tribal farm, resulting in a total of 929 acres planted compared to 1,009 planned. There were 438 acres of corn and sunflowers compared to 484 planned; 491 acres of wheat and barley compared to 525 planned; 410 acres of hay, improved pasture and set aside harvested or used compared to 418 planned; and only 380 acres of native pasture was used compared to 674 planned. This latter difference occurred because only 165 calves were summer grazed compared to 245 planned. There were 50 cows, 42 calves for overwintering, 13 replacement heifers, 2 bulls, and 17 buffalo, all of which were close to the figures in the plan. There were only 165 head finished in the feedlot during the winter, however, compared to 316 head planned. This difference was caused primarily by the delay in building the feedlot, which will not be in place until fall of 1980. The end result was the tribal farm just broke even before subtracting depreciation on equipment.

Despite the differences noted between the suggested plan and the actual activity levels, it is clear that the linear programming model has had a major effect on the decision-making process for the tribal farm. It has provided the tribe with a set of evaluated alternatives and tribal leaders have used the model to explore the implications of their ideas. This corresponds closely with the main advantage of agricultural sector models in developing countries cited by Langham. In order to have a lasting impact on the decision-making process, however, the investigative capacity of the model must be institutionalized into tribal decision making. This raises the question of how the model will be updated.

[8] The appropriate discount rate is dependent on several factors (Norton, p. 88). A sensitivity analysis was done in which the discount rate was varied from 6% to 10%, and the resulting plans were not particularly sensitive to this parameter.

[9] It was necessary to remove the discounting of values in the new objective function before making this comparison since it was not necessary to discount in the initial objective function.

Updating the Plan

Annual updating of the model will be a key to future planning efforts. The updating process will initially involve the following steps: (*a*) The tribal staff person monitoring the farm will send a list of possible new tracts of land, an inventory of crops and livestock on hand, information on loans outstanding, and other information to the person updating the linear programming model. (*b*) Crop, livestock, and input prices will be updated and the crop and livestock budgets regenerated. (*c*) This information will then be entered into a computer program which will revise the model. (*d*) A series of computer runs will be made with the model under varying levels of risk. (*e*) Tables showing projected profit and loss, the crop and livestock plans, monthly cash requirements, labor requirements, machinery and building investments, borrowing requirements, and the effects of relieving certain constraints or forcing in nonoptimal activities will be discussed with the tribal decision makers. One of the plans will then be selected or, at the tribe's request, the model will be rerun forcing certain activities into or out of the solution.

There is a possibility that a member of the tribal planning staff could be trained to run the linear programming model. The tribe has recently hired a natural resource planner with some computer experience. The tribe could connect through a telephone hookup to computers at South Dakota State University or the University of Minnesota. A great deal of care must be exercised, however, to ascertain that tribal planning personnel with responsibility to use the model, adequately understand it. Otherwise, there is a significant danger that erroneous results could be generated without their being aware of it. In the coming year, one of the authors will do the updating.

Concluding Comments

The type of analysis conducted in the Sisseton study is an attempt to provide tribal leaders with planning tools capable of considering the interrelationships among crop and livestock alternatives over time. The LP model provides plans consistent with the major components of the tribal resource base, goals, and decision-making structure. The Sisseton-Wahpeton Sioux Tribe feels the plans generated fit their needs and have generally followed the one generated for 1979.

It is clear from the LP results that the tribal farm can contribute to the objectives of providing a small economic base and helping the tribe maintain control over its land base. However, the effects on income and employment of tribal members will be mostly indirect, because profits will not be distributed and the size of the farming operation projected over the next five years is small in relation to the size of the reservation. There will be some income and employment multiplier effects; and, if the farm is successful, the tribe undoubtedly will take pride in managing a viable economic venture. In addition, the farm may attract capital for expansion in other areas on the reservation. Tribal farming will never be a major source of employment on the reservation but may have a useful role as a part of an overall development program. The tribal farm also provides examples and can be used for training of individual Indian farmers.

An important question is whether the planning approach used here might be useful for other tribes. A brief look at certain aspects of the project provides some insights into the answer to this question.

The LP model contains a good deal of reservation-specific information which was needed to provide reliable results. This means that modifications in activities and constraints as well as coefficients would have to be made before transferring it to other situations. The basic structure, however, could be transferred to other settings without much difficulty. This type of analysis is especially useful in situations where the resource base allows a large number of production alternatives.

A number of aspects besides the analytical technique were important to any success the Sisseton project has experienced. Frequent communication with the tribe was of primary importance in all stages. Personal communication was used to transfer ideas, to obtain feedback, to develop credibility, and to provide a general understanding of what a linear programming model is and how tribal planning personnel can interact with it.

Second, the tribe was committed to the project and participated in terms of time, labor, ideas, and money. A good indication of their commitment was their attempts to solve their own agricultural problems even before they solicited outside assistance.

Third, the plan involved an adaption of the current situation rather than a drastic change in what was already being done. Plans were

also kept flexible. In 1978, for example, they were altered, first, to compensate for credit difficulties and, second, to compensate for a slowness in constructing a fence. Changes also occurred in the 1979 plan as noted above.

A fourth important aspect of the project was the strong technical support from various institutions such as South Dakota State University. Information and assistance were needed from a number of disciplines, and the tribe needed to be advised where they could obtain various types of technical assistance.

The real cost to the tribe of the planning project was about $2,500 per year for two years, which represented about 15% of the total project cost. The remainder was provided by the institutions noted earlier.[10] Part of the project cost, however, resulted from time spent evaluating the feasibility of other activities, such as a slaughterhouse, a poultry operation, and a sunflower processing plant, as well as from time spent developing an agricultural training program. The tribe will bear 100% of the cost of updating the tribal farm plan.

Another important question is, will the SWST continue to support the planning process described here and, indeed, will it continue to support the tribal farm? The farm and the planning approach have received strong support from the tribal chairman and planning director. Tribal activities often are not fully understood, however, at the grass roots level on the reservation. In addition, small groups of tribal members frequently try to work together to improve their economic positions at the expense of the rest of the tribe. Also, it is common for a new political administration on the reservation to try to replace as many of the programs begun by the previous administration as possible. To prevent this, tribal leaders have been exploring possibilities for restructuring the first level of decision making, such as incorporating the tribal farm and selecting a board of directors.

Careful planning is a necessary, but not a sufficient, condition for a financially successful tribal farm. Among the other conditions are factors influencing the implementation of the plan, such as the dedication and skill of the labor force. The farm changed managers in April 1980. The new farm manager is an Indian. Before hiring the new manager there was a great deal of discussion within the tribe about whether a tribal member could be placed in this position. The issue revolves not around just skill but around the Dakota cultural system.[11] Workers on the farm are also Indians, and the turnover has been fairly rapid. It is important for the labor situation to stabilize.

There is evidence that other tribes are watching the Sisseton planning approach to see if this is a strategy that they can pursue. It is perhaps premature to estimate the financial return to this planning effort, but the Sisseton-Wahpeton Sioux tribal leaders feel strongly that it has been worthwhile.

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References

Brink, L., and B. McCarl. "The Tradeoff between Expected Return and Risk among Corn Belt Farmers." *Amer. J. Agr. Econ.* 60(1978):259–63.

Demallie, R. J. "Pine Ridge Economy: Cultural and Historical Perspective." *American Indian Economic Development*, ed. S. Stanley. Chicago: Aldine Publishing Co., 1978.

Dorner, P. "The Economic Potential of the American Indian: Their Resources and Potential for Development." Ph.D. thesis, Harvard University, 1959.

Fitch, J. "Economic Development in a Minority Enclave: The Case of the Yakima Indian Nation, Washington." Ph.D. thesis, Stanford University, 1974.

Hazell, P. B. R. "A Linear Alternative to Quadratic and Semivariance Programming for Farm Planning under Uncertainty." *Amer. J. Agr. Econ.* 53(1971):53–67.

Langham, M. R. "On Systems Models for Agricultural Sector Analysis and Research Priorities for Developing Countries." Paper presented at the Regional Seminar on Agricultural Sector Analysis, sponsored by the Agricultural Development Council, 8–11 Nov. 1976.

Levitan, S. A., and W. B. Johnston. *Indian Giving, Federal Programs for Native Americans.* Baltimore, Md.: Johns Hopkins University Press, 1975.

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[10] It is interesting to note the absence of the Bureau of Indian Affairs (BIA) in this planning effort. Demallie has noted recently a growing tendency to bypass the BIA when possible and to attempt to minimize its role on the Pine Ridge Reservation. The SWST is perhaps one of the few tribes with a well-organized tribal planning staff independent from the BIA. This planning staff handles the leasing of all tribally owned land, develops housing plans, health plans, natural resource management plans, and other such matters.

[11] The manager, if he is a tribal member, has to come to grips with a cultural system that dictates that every man is completely independent and equal and that no one has the right to tell anybody what to do. In addition, the moral system of kin relationships demands that an individual share with his relatives (Demallie, p. 298). As a result, it is difficult for a tribal member as manager to direct the activities of the labor force or to say no to requests for use of farm equipment, gasoline, or other goods.

Norton, G. W. "A Model for Indian Reservation Agricultural Development: The Case of the Sisseton-Wahpeton Sioux." Ph.D. thesis, University of Minnesota, 1979.

Schurle, B., and B. Erven. "Sensitivity of Efficiency Frontiers Developed for Farm Enterprise Choice Decisions." *Amer. J. Agr. Econ.* 61(1979):506–11.

Sorkin, A. *American Indians and Federal Aid.* Washington, D.C.: The Brookings Institution, 1971.

Thomsen, K. J., and P. B. R. Hazell. "Reliability of Using the Mean Absolute Deviation to Derive Efficient E-V Farm Plans." *Amer. J. Agr. Econ.* 54(1972):503–6.

Trosper, R. L. "American Indian Relative Ranching Efficiency." *Amer. Econ. Rev.* 68(1978):503–16.

U.S. Department of Interior, Bureau of Indian Affairs (BIA). *The Sisseton Reservation Area, Its Resources and Potential.* Billings, Montana, 1972.

Machinery Selection Modeling: Incorporation of Weather Variability

Abdulla B. Danok, Bruce A. McCarl, and T. Kelley White

An alternative analytical approach to the important and complex machinery selection problem is proposed. A mathematical programming model is developed which embodies (*a*) the integer nature of machinery decisions, (*b*) the stochastic nature of weather, (*c*) the joint selection of machinery and crop plans, and (*d*) selection among machinery sets rather than among individual machines. Optimal machinery and crop plans are determined for selected weather probability levels. The robustness of machinery sets over a range of weather conditions is evaluated by subjecting the distributions of outcomes for alternative machinery sets to stochastic dominance criteria. Bias of good-field-day distributions is also discussed.

Key words: machinery selection, mixed integer programming, stochastic dominance.

The machinery selection decision confronting farmers is recurrent, complex, and important. Machinery by its nature begins to deteriorate or become obsolete from the moment of purchase. Thus, the established farmer must continually choose whether to keep, upgrade, or replace items of equipment. Conversely, the beginning farmer must select machinery with which to begin operations. Machinery selection is complicated by many interrelated factors which jointly determine the final impact of a particular machinery decision on farm profitability (or other goals). Among the more important factors that should be considered in the selection of machinery are (*a*) weather conditions, especially as related to the probability distribution of availability of time for fieldwork during critical seasons; (*b*) the effect of timeliness of operation on yield; (*c*) availability of labor at crucial times of the year; and (*d*) the farmer's goals and attitudes toward risk. The interaction among these factors as they influence crop planning and machinery selection imply that machinery selection and crop planning should be considered simultaneously.

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The importance and complexity of the machinery selection problem has resulted in numerous efforts to develop analytical models which will either yield generalizable selection guidelines or be useful directly by the farmer as a decision aid. The approaches that have been proposed are (*a*) calculator-type programs (e.g., Von Bargen and Hines), (*b*) simulations (e.g., Donaldson, Sorensen and Gilheany), and (*c*) mathematical programming approaches (e.g., Danok, McCarl, White; Kletke and Griffin). To date, many sophisticated models have been developed, but to the authors' knowledge only simple budgeting and static linear programming (LP) approaches (as discussed in Brink and McCarl) have had extensive extension application and farmer use.

The research reported in this paper is an attempt to develop an alternative analytical approach to machinery selection problems. First, a mathematical programming model is developed which embodies (*a*) the integer nature of machinery decisions, (*b*) the stochastic nature of weather, (*c*) the joint selection of machinery and crop plans, and (*d*) selection among machinery sets rather than among individual machines. Then alternative ways of employing the model to choose "good" machinery sets are explored.

A Model Based on Machinery Sets

Mixed integer programming is an appropriate modeling technique for the crop and ma-

chinery choice problem. The model developed herein is a mixed integer model (MIP). This model, however, differs in one important aspect from previous work (e.g., Danok, McCarl, White; Kletke and Griffin). Unlike earlier formulations, the machinery representation is operationalized as a choice among sets of machinery rather than individual machines. This is based upon several considerations. First, the authors feel that the essential reason simple budgeting and linear programming have been successful in extension is they impart a degree of control over the machinery selection process to the farmer. The generation of technically balanced machinery sets is done easily with MIP, yet technical balance alone is not sufficient for farmer purposes. Control is necessary to assure consistency of the selected set with an individual farmer's situation (e.g., existing equipment, institutional arrangements). The second advantage of the proposed approach is the power of MIP, which by nature evaluates multiple alternatives efficiently. Thus, consideration of multiple sets can be accomplished with MIP without a cumbersome set-by-set search using linear programming. The set concept embodies mutually exclusive machinery sets which lead to an MIP with a number of feasible integer solutions equal to the number of alternative machinery sets. This is much smaller than in other machinery MIP formulations (e.g., Danok, McCarl, White; Kletke and Griffiin).

The machinery selection model proposed is as follows:

$$\text{(1)} \quad \underset{\substack{Y_j = (0,1) \\ X_{jk} \geq 0}}{\text{maximize}} \quad \sum_j C_j Y_j + \sum_j \sum_k d_{jk} X_m$$

$$\text{(2)} \quad \sum_j e_{ij} Y_j + \sum_j \sum_k a_{ijk} X_{jk} \leq b_i \quad \text{for all } i$$

$$\text{(3)} \quad \sum_j Y_j = 1$$

$$\text{(4)} \quad M Y_j + \sum_k X_{jk} \leq 0 \quad \text{for all } j$$

$$\text{(5)} \quad \sum_j \sum_k g_{Ljk} X_{jk} \leq f_L \quad \text{for all } L$$

where c_j is the annualized cost of machine set, j, Y_j is a zero-one variable indicating whether machine set j is adopted, e_{ij} is the amount of resource i provided by machine set j, d_{jk} is the per unit return to cropping activity K using machine set j, X_{jk} is the number of units of cropping activity k employed using machine set j, a_{ijk} is the per unit usage of resource i by cropping activity X_{jk}, g_{Ljk} is the per unit usage of resource L by cropping activity X_{jk}, b_i is the farm's endowment of resource i, f_L is the farm's endowment of resource L, and M is a number larger than the number of acres which can be treated by any set times the number of operations.

The model maximizes profit, which is cropping profit less machinery cost, subject to (a) constraints on resources which link machinery and cropping activities, (b) constraints that reflect mutual exclusivity of machinery,[1] (c) constraints which link machine set purchase and use, (d) and constraints on other cropping resources.

Consideration of Uncertainty in Field Time Availability

Weather affects farm production and profitability in numerous ways, but the effect most directly associated with machinery selection is uncertainty in the time available for field work. Available field time is an important constraint in mathematical programming models of crop production and machinery selection-use. However, the means for realistically reflecting uncertain field time availability on the model constraints is not necessarily obvious. Several approaches are possible. For example, the average time available may be used for each period, or, conversely, conservative (or optimistic) estimates of field time may be generated by discounting average field time [using the essence of chance constrained programming (Charnes and Cooper)]. The most common approaches involve discounting of field time available. This often leads to selection of a larger machinery set that can perform well under poor conditions (Kletke and Griffin). In following this approach, the time specified for each period is the minimum time which would be available at a prespecified probability level, say 85% of the years.[2] The

[1] Mutual exclusivity is not absolutely necessary. In some types of applications it may be desirable to have, for example, tillage and harvesting sets.

[2] In the Purdue Model B-9 (Doster and McCarl), the seventeenth worst year out of twenty was chosen.

choice of this probability level is arbitrary. Wagner (p. 675), in discussing chance-constrained programming, states that "B_1 (the probability level) should be part of the optimization problem." Alternatives to period-by-period discounting would involve running the model repeatedly with either actual or randomly selected weather years. Such approaches would be suspect in a mathematical programming model due to the certainty assumption (i.e., the model is given perfect knowledge of time available).

This study will use the period-by-period chance-constrained approach. However, our interest is in maximum profit and in robustness of machinery to many types of weather assumptions. Formally, the model to be solved will be the same as (1)–(5) above. However, the estimates of field time available (e, b, f) will be formed so that these elements are discounted for uncertainty. Further, the probability level will be changed and the effect of different probabilities explored.

Robustness and Stochastic Dominance

Because weather is variable, farmers most likely would choose a machinery set that performs well under a wide range of weather conditions. This characteristic will be referred to as robustness herein. Machinery sets will be tested under a wide variety of time availabilities to determine their robustness. This produces a distribution of outcomes for each machine set which is appropriate for the application of stochastic dominance (Anderson, Meyer).

Stochastic dominance generally refers to a set of techniques wherein distributions are compared under the basic assumptions that any decision maker prefers more income to less (degree 1) and that, as income increases, less variability is preferred to more (degree 2). Meyer has also introduced a form of stochastic dominance in which comparisons are made utilizing limits on the Pratt risk-aversion parameter.

Stochastic dominance provides an approach to machinery selection. Given a probability distribution of machinery performance under uncertain field time, stochastic dominance analysis may be applied to choose a machine set that is robust to a wide range of field time outcomes. This is an alternative to choosing the optimal set for a specific set of field times.

Case Analysis

The above machinery selection modeling proposals are applied to a hypothetical case farm. The farm is a 600-acre cash grain farm in central Indiana. Four crops are considered: corn, soybeans, wheat, and double-crop soybeans. The farm characteristics are essentially those of Purdue's Model B (McCarl, Doster, Candler, Robbins). Danok provides details on specification.

The base analysis was carried out over fifteen machinery sets which were developed in conjunction with knowledgeable extension specialists (Parsons, Doster). These sets (see Danok for details) were used in both a mixed-integer programming model and in a linear programming model. Within both models good-field-days data for the twenty-two periods in the years 1960–77 (from the Purdue agricultural statistician as discussed in Danok) were used to calculate the right-hand side values. The periods include eleven spring periods during which plowing, planting and post-planting of corn and soybeans are done; five early summer during which post-planting for corn and soybeans, wheat harvest, and double-crop planting are done; and six fall periods in which wheat planting, fall plowing, and harvesting operations are done. The field days' right-hand side corresponds to the minimum number of good field days that would be expected with the stated level of probability. The probabilities used were .1, .15, .33, .5, .6, .67, and .9.

Mixed Integer Programming Application

An MIP based upon (1)–(5) was formulated and solved. An overall schematic of the model is presented in figure 1. The model maximizes profit subject to constraints on (a) machinery ownership—a constraint which insures that only one machinery set is chosen [equation (3) above]; (b) tractor time—constraints which link tractor time provided by the machinery sets with use by period [equation (2) above]; (c) machinery set presence—constraints which relate machinery set presence to activities which use that machine set [equation (4) above]; (d) land, a limit on land available; (e) land reconciliation, a limit which restricts land used during any time period to be less than or equal to total land available; (f) labor availability—a constraint which balances labor use with labor available from hired and

Constraint	Machinery Sets Ownership	Plowing	Discing	Crop Production	Hired Labor	Crop Marketing	Input Purchase	Income	Right-Hand Side
		Activity							
Objective function	−							+	
Machinery ownership	+								= +
Tractor time	−	+	+	+					≤ 0
Machinery sets presence	−	+	+	+					≤ 0
Land		+							≤ +
Land reconciliation		+		+					≤ +
Labor availability		+	+	+	−				≤ +
Hired labor					+				≤ +
Land preparation time:									
a. Plowing time		+							≤ +
b. Discing time			+						≤ +
Crop production time									
a. Planting time				+					≤ +
b. Harvesting time				+					≤ +
Land precedence									
a. Land ready to disc		−	+						≤ 0
b. Land ready to plant			−	+					≤ 0
Yield				−		+			≤ 0
Input purchase				+			−		≤ 0
Income				+	+	−	+	+	< 0

Figure 1. Schematic of model matrix

on-farm sources by period; (*g*) hired labor—a limit on hours of hired labor available by time period; (*h*) plowing time—a limit on hours of plowing time available by time period (assumed constant across machine sets); (*i*) discing time—a limit on hours of discing time available by time period (assumed constant across machine sets); (*j*) planting time—a limit on hours of planting time available by time period (assumed constant across machine sets); (*k*) harvesting time—a limit on hours of harvesting time available by time period (assumed constant across machinery sets); (*l*) land ready to disc—a constraint which links plowed ground supply with plowed ground use (discing) by time period; (*m*) land ready to plant—a constraint which links ground that has been plowed and disced with its use (planting) by time period; (*n*) yield—a set of rows balancing production with sale by crop; (*o*) input purchase—a set of rows balancing input use with input purchase; and (*p*) income—an income-accounting row.

The activities in this model are (*a*) machinery set ownership, activities representing the adoption of various machinery sets; (*b*) plowing, activities for plowing by crop, time period, and machine set; (*c*) discing, activities for discing by crop, time period, and machine set; (*d*) crop production, activities for planting thru harvesting by crop, planting date, harvesting date, and machine set; (*e*) hired labor, activities representing the hiring of labor by period; (*f*) crop marketing, activities representing sale of each crop; and (*g*) input purchases, activities representing purchases of each input.

Solution Method

The mixed-integer programming model is, as formulated, particularly adaptable to solution by iterative methods. Clearly, one alternative is to solve an LP for each machinery set and pick the best. However, given the formulation structure, Benders decomposition (Benders; Danok, McCarl, White; Hilger, McCarl, Uhrig) is a particularly appropriate solution method and is used to solve this model.[3]

MIP Results

The first approach to machinery selection used in this study was to solve the MIP model for optimal machinery set and crop plan under specified weather assumptions. The results of the seven runs of the model are presented in table 1. The principal results obtained are as follows:

(*a*) As long as available field time is an effective constraint, the optimal machinery set changes as the weather probability is increased (i.e., the amount of field time available is increased). At higher probability levels, other constraints become more important.

(*b*) The size (capacity in acres per unit of time) of the optimum machinery set decreases as weather probability (available field time)

[3] Although not implemented here, the mutual exclusivity of machine sets allows the problem to be reduced to a small MIP and a one machine-set LP, given the machine set chosen. Thus, a series of ordinary farm-planning models can be solved. The only difficulty arises from the need for dual variables on constraints, equation (4). However, analysis of the formulation (as in Geoffrion and Graves) allows the dual variables to be constructed analytically (see Danok for details).

Table 1. Net Farm Income, Optimal Machinery Set, Crop Acreage by Weather Probability Level for 600-Acre Farm

	Weather Probability Level						
Item	.1	.15	.33	.5	.6	.67	.9
Net farm income ($)	79,773	127,462	147,438	148,584	149,166	149,583	150,221
Selected machinery set	9	9	11	2	2	2	2
Plowed acres	387.2	600	600	600	600	600	600
Disced acres	437.5	600	600	600	600	600	600
Planted and harvested acres							
a. Corn	104.6	266.6	600	600	600	600	600
b. Soybeans	282.6	333.4	0	0	0	0	0
c. Wheat	50.3	0	0	0	0	0	0
d. Double-crop	0	0	0	0	0	0	0
Crop sales (bushel)							
a. Corn	14,721	37,927	86,162	85,953	86,207	86,358	86,694
b. Soybeans	12,500	14,865	0	0	0	0	0
c. Wheat	2,882	0	0	0	0	0	0
d. Double-crop	0	0	0	0	0	0	0

increases. The important variable determining net farm income is the amount of work that can be accomplished during critical time periods in the spring and fall. Obviously, more machine capacity and more field time during a given period are substitutes.

(*c*) Given the resource constraints used to define the typical farm employed in this study, field time and machine capacity cease to be effective constraints as weather probability increases. Thus, at a weather probability of .33, it is possible to plant all land in corn (the crop giving the highest return to land). At a probability of .5 and greater, it is possible to plant and harvest corn at the most favorable time. Thus, as available field time increases, the farm becomes specialized in corn; further, the least-cost machinery set for corn production is chosen and net farm income stabilizes.

Solution performance of the model is discussed extensively by Danok. The number of machine sets examined by a run in order to conclude optimality varied between two and nine, and exhibited an inverse correlation with the probability level used.[4]

Use of MIP to Modify Existing Machinery Set

The MIP results discussed above were derived from a specification that assumed no existing machinery set on the farm. The more normal situation is that a farmer possesses a set of machinery and wants to evaluate alternative modifications of that set. In order to demonstrate the usefulness of the MIP model in this situation, a particular machine set was assumed and alternatives generated. Shadow prices obtained from solving the crop-planning model with this existing machinery set indicated that it was characterized by (*a*) excess plowing and tractor capacity, (*b*) insufficient planter capacity, and (*c*) insufficient harvesting capacity. The MIP model was then respecified with eight integer activities—one representing the existing set and seven representing modifications including various combinations of machines that could correct one or more of the deficiencies of the existing set. Machinery acquisition activities reflected cost and performance of the existing set and the existing set with alternative modifications.

When the respecified MIP model was run, a modification of the set that included less tractor capacity and more harvesting capacity was chosen. Thus, the MIP model was shown to be an effective tool for evaluating alternative modifications of existing machinery sets as well as choosing among totally new sets.

Stochastic Dominance

The MIP results for alternative weather probability levels (table 1) would be of limited use to a farmer in making a machinery decision. Clearly, within limits, the choice of a probability level for good field days is arbitrary. The results show that when different probability levels are chosen, different "optimal" sets result. Thus, the farmer would not receive a clear indication of which set to use. Farmers, however, potentially are interested in a trade-off between robustness and expected profit. Consequently, two questions arise: (*a*) which probability level should be used (Shurley and McCarl examine this), and/or (*b*) can a machine set be chosen for which the probability level does not matter that much? Question (*b*) led to the stochastic dominance analysis.

Each of the original machine sets was imposed on the model, and it was run for nine different probability levels. Table 2 presents the results. From these results, a cumulative probability distribution of net farm income was formed for each machinery set. Stochastic dominance analysis, as discussed above, was applied to these distributions to choose dominant sets (assuming them to be unbiased as discussed below). Using the distributions, first and second degree stochastic dominance tests were applied. Table 3 displays the results.

Distributions for machinery sets 1, 2, 3, 4, 8, 9, and 11 form a group with first-degree dominance over the remaining distributions. If one is willing to make the assumption that more income is preferred to less, then these machine sets eliminate the other machine sets from consideration. From this group, distributions 1, 3, and 9 dominate the others under second-degree stochastic dominance. Under the assumptions that more is preferred to less and that the farmer is risk-averse (and, naturally, that the distributions are proper), then these distributions eliminate all other distributions. Stochastic dominance tests, as in Anderson, do not distinguish among these three machine sets.

Meyer has provided a method by which dis-

[4] Computer time and cost in an inefficient implementation (a better implementation is discussed in footnote three) varied from 1,600 seconds ($51) to 900 seconds ($26), depending upon number of Benders cuts required.

Table 2. Net Farm Income Generated by Using Different Machinery Sets on 600-Acre Farms under Different Weather Probability Levels

Machinery Set No.	Weather Probability Level								
	.1	.15	.2	.3	.33	.5	.6	.67	.9
1	68,698	118,597	138,616	144,573	144,942	145,934	146,206	146,364	146,001
2	54,803	100,085	135,530	145,639	146,563	148,584	149,166	149,583	150,221
3	65,772	117,383	139,444	145,686	146,055	147,046	147,318	147,477	148,104
4	56,513	109,836	139,838	145,572	145,642	146,014	146,286	146,445	147,072
5	54,633	107,912	137,737	143,474	143,544	143,916	144,188	144,347	144,973
6	60,537	109,418	133,900	146,614	141,458	143,592	144,257	144,723	145,356
7	65,120	114,654	134,604	140,631	141,000	141,992	142,263	142,422	143,049
8	78,493	122,744	136,842	140,764	141,253	142,330	142,408	142,454	142,484
9	79,773	127,462	138,646	141,103	141,197	141,618	141,696	141,741	141,772
10	60,796	109,461	133,847	140,646	141,490	143,625	144,189	144,755	145,388
11	56,158	103,997	140,587	147,069	147,438	148,430	148,702	148,861	149,487
12	77,868	127,082	128,253	140,366	140,461	140,881	140,959	141,005	141,036
13	62,401	113,317	138,277	143,999	144,069	144,442	144,713	144,872	145,499
14	49,957	88,689	132,511	146,711	146,979	147,350	147,526	147,628	148,214
15	54,111	99,361	135,781	143,572	144,416	146,551	147,215	147,681	148,314

tributions may be compared with respect to ranges of the Pratt risk-aversion coefficient. Application of this method shows that distribution 3 is preferred to distributions 1 and 9 for a Pratt risk-aversion coefficient between .000001 and .1.[5] The stochastic dominance analysis then suggests the choice of machine set 3. This leads to an interesting observation, because machine set 3 was not optimal under any of the various weather probability levels (table 1). Thus, a farmer interested in robustness may choose a machine set which is not optimal under any individual state of nature but which behaves well over a wide range of states of nature. This leads one to doubt the utility of using the MIP model with a given weather expectation as a means of choosing machinery.

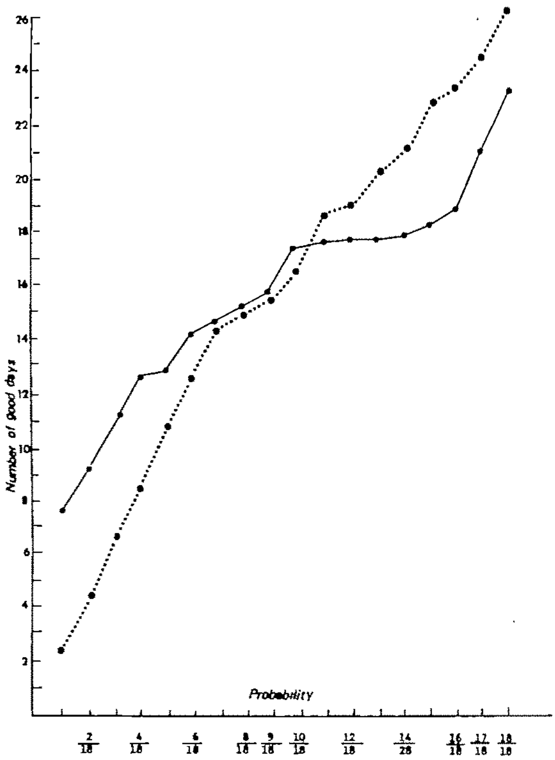
Bias in Distributions

Because of the method used in constructing the MIP right-hand sides, the probability distributions used in the stochastic dominance analysis are biased. The results would be unbiased only in the case of perfect correlation

[5] The Pratt risk-aversion coefficient appears to be most likely to appear in this range based upon its theoretical properties [one divided by expected income for the utility function log of income (Lin and Chang)] and its equality to the risk-aversion parameter from an EV portfolio selection model (Lin and Chang display this relationship). Values for this parameter are given in Lin, Dean, Moore, table 2, p. 504, where the Pratt coefficient varies from 0 to .02 (neglecting subject 5), and Weins (.0085–.091).

Table 3. Stochastic Dominance Results

Distribution	Distributions This One Dominates		Distributions This One is Dominated By		Distribution Over Which There Is No Dominance
	First-Degree	Second-Degree	First-Degree	Second-Degree	
1	5,6,7,10,13	2,4,14,15			3,8,9,11,12
2	14	15		1,3,11	4,5,6,7,8,9,10,12,13
3	5,6,7,10,13	2,4,11,14,15			1,8,9,12
4	5	14,15		1,3	2,6,7,8,9,10,11,12,13
5			1,3,4,13	8,9,12	2,6,7,10,11,14,15
6			1,3,13	8,9,10,12	2,4,5,7,11,14,15
7			1,3	8,9,12	2,4,5,6,10,11,13,14,15
8	10	5,6,7		9	1,2,3,4,11,12,13,14,15
9	12	5,6,7,8,10			1,2,3,4,11,13,14,15
10		6	1,3,8,13	9,12	2,4,5,7,11,14,15
11	14,15	2		3	1,4,5,6,7,8,9,10,12,13
12		5,6,7,10,14	9		1,2,3,4,8,11,13,15
13	5,6,10	14	1,3		2,4,7,8,9,11,12,15
14			2,11	1,3,4,12,13,14	5,6,7,8,9,10
15		14	11	1,2,3,4	5,6,7,8,9,10,12,13



Key: solid line is summed four-week distribution. Dotted line is horizontal sum of four-week distribution.

Figure 2. Comparison between distribution of good days selected period by period and for group of periods

among all time periods. The nature of the bias was examined by taking the actual good field days for a four-week spring period and comparing the distribution of the time available during the period with the horizontal sum (at each probability level) of the distribution of the individual weeks. Figure 2 portrays the two distributions. Clearly, the use of period-by-period expectations biases the distribution. What is deemed to occur at low probabilities from the summed individual distributions in fact is much less likely when examining the possibilities from the four-week distribution. For example, less than seven good field days did not occur in the 1960–77 period for the individual distributions, taking the worst possible event in each period and summing yields 2.5 days. On the other hand, good-field-days distribution at the high end should, in fact, have lower probability. These results do indicate bias in the distributions. We feel, however, that first-degree stochastic dominance would yield the same results, regardless. Under this sort of bias, the second-degree criterion would be altered. The discovery of the correct probabilities for a chance-constrained probability level is virtually impossible in the context of this study. The probability depends not only upon the total number of field days across periods but also upon the number of field days within each period. The dominance criterion, however, does appear to be useful in this case (when the bias is understood) and very attractive in cases where an unbiased distribution of outcomes may be constructed (i.e., possibly through Monte-Carlo simulation, as in Edwards).

Concluding Comments

The effect of field time uncertainty on machinery selection was not surprising. First, the results presented herein reaffirm the rather obvious conclusions that pessimistic field time estimates result in the farm carrying larger machinery (as in Kletke and Griffin and undoubtedly many other places). Second, field time uncertainty tends to discourage those crops which are planted in the more uncertain periods. Third, model income rises as field time expectation becomes more optimistic. However, income increases at a decreasing rate and virtually no increase occurs for a field time expectation above the average. This would have some implications for returns to weather modification efforts.

The most fundamental question to be addressed in concluding this paper is: How should machinery selection be modeled? Four alternative approaches appear to be suggested by this and other studies. First, mixed-integer programming with individual machines (not sets) may be used. A second approach would be mixed-integer programming with sets. Third, a distribution of outcomes for alternative machinery sets can be generated and stochastic dominance (or some other risky choice criterion) applied. Fourth, simple budgeting or deterministic models can be used to examine the impact of alternatives. Clearly, combinations of the above may also be used.

Machinery selection obviously may be done for a multitude of purposes. Research objectives may emphasize the desire to know how machinery complements will change, given various changes in the farm environment. Extension objectives could focus on the desire to provide a tool for farmer use and/or education objectives in terms of problem formulation and resolutions.

Many types of research objectives would seem to be best met by either the first, second, or third methods. The mixed-integer results seem to be heavily biased by the good field days expectation level; thus, some distributional approach may be desirable. This is particularly evident when one considers that the stochastic dominance approach resulted in the choice of a machine set which which was not optimal under any probability level but did well overall.

For extension and some types of research, we feel that the machine set idea is extremely promising. The MIP model is computationally tractable (which has been an obstacle in previous studies) and with sets, can handle more of the farm level realities. Further, the burden of definition of machine-set alternatives is placed on the decision maker (as in the commonly used budgeting approaches). This, however, should not be too difficult except for the new farmer, as we feel many farmers will have an idea of what changes are potentially attractive. Shadow price information also is generated to aid in machine set definition and refinement. The farmer then controls the domain of feasible machinery. True optimality, however, may not be attained.

A tempting and seemingly attractive machinery selection strategy would be to use the MIP to select some machine sets. Information about the marginal costs of other sets could be used to choose a few other machine sets. From here some sort of distribution-generating model (probably different from the approach used in this study because of the problem of bias) could be used in conjunction with stochastic dominance to study these machine sets in detail. This probably would be an acceptable research technique but might be awkward in an extension setting.

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References

Anderson, J. R. "Risk Efficiency in the Interpretation of Agricultural Production Research." *Rev. Mktg. Agr. Econ.* 42(1974):131–84.

Benders, J. F. "Partitioning Procedures for Solving Mixed-Variables Programming Problems." *Numerische Mathematick* 4(1962):238–52.

Brink, L. G., and B. A. McCarl. "The Adequacy of a Crop Planning Model for Determining Income, Income Change and Crop Mix." *Can. J. Agr. Econ.* 27(1979):13–25.

Charnes, A., and W. W. Cooper. "Chance-Constrained Programming." *Manage. Sci.* 6(1959):73–79.

Danok, Abdulla B. "Effect of Weather Variability on Machinery Selection." Ph.D. thesis, Purdue University, 1979.

Danok, A. B., B. A. McCarl, and T. K. White. "Machinery Selection and Crop Planning on a State Farm in Iraq." *Amer. J. Agr. Econ.* 60(1978):544–49.

Donaldson, G. F. "The Study of Agricultural Systems: Application to Farm Operations." *Study of Agricultural Systems*, ed. G. E. Dalton. London: Applied Science Publishers, 1975.

Doster, H. Private Communication, Dep. Agr. Econ., Purdue University, Sep. 1978.

Doster, H., and B. A. McCarl. *Purdue Crop Budget Model B-92.* Purdue University Coop. Extens. Serv., EC 447, June 1975.

Edwards, W. M. "Farm Machinery Selection under Conditions of Uncertainty." Ph.D. thesis, Iowa State University, 1979.

Geoffrion, A., and G. Graves. "Multi-Commodity Distribution System Design by Benders Decomposition." *Manage. Sci.* 20(1974):822–44.

Hilger, D. A., B. A. McCarl, and J. W. Uhrig. "Facilities Location: The Case of Grain Subterminals." *Amer. J. Agr. Econ.* 59(1977):674–82.

Kletke, Darrel D., and Steven G. Griffin. "Machinery Complement Selection in a Changing Environment." Dep. Agr. Econ., Oklahoma State University, 1976.

Lin, W., and H. Chang. "Specification of Bernoullian Utility Function in Decision Analysis." *Agr. Econ. Res.* 30(1978):30–36.

Lin, W., G. Dean, and C. Moore, "An Empirical Test of Utility versus Profit Maximization in Agricultural Production." *Amer. J. Agr. Econ.* 55(1974):497–500.

McCarl, B. A., H. Doster, W. V. Candler, and H. P. Robbins. "Experiences with Farmer-Oriented Linear Programming for Crop Planning." *Can. J. Agr. Econ.* 25(1977):17–30.

Meyer, J. "Second Degree Stochastic Dominance with Respect to a Function." *Int. Econ. Rev.* 18(1977):477–87.

Parsons, S. Private Communication. Dep. Agr. Eng., Purdue University, Sep. 1978.

Pratt, J. W. "Risk Aversion in the Small and in the Large." *Econometrica* 32(1964):422–36.

Shurley, W. D., Jr., and B. A. McCarl. "Weather Uncertainty and its Impacts on Machinery Decisions and Accuracy of Farm Planning Models." Unpublished paper, Dep. Agr. Econ., Purdue University, 1980.

Sorensen, E. E., and J. F. Gilheany. "A Simulation Model for Harvest Operations under Stochastic Conditions." *Manage. Sci.* 16(1970):549–65.

Wagner, H. *Principles of Operations Research.* Englewood Cliffs, N.J.: Prentice-Hall, 1975.

Weins, T. "Peasant Risk Aversion and Allocative Behavior: A Quadratic Programming Experiment." *Amer. J. Agr. Econ.* 58(1976):629–35.

Von Bargen, K., and J. Hines. "Economic Analysis of a Complement of Farm Machines." ASAE Paper 73-1529, American Society of Agricultural Engineers, St. Joseph, Michigan, 1973.

Reforming Cameroon's Government Credit Program: Effects on Liquidity Management by Small Farm Borrowers

Francois Kamajou and C. B. Baker

Higher interest rates and credit limits as well as modified lending practices have been proposed to improve the performance of credit programs for small farmers in developing countries. Models based on Cameroon field data are used to generate results from such reform proposals. The results suggest that small farmer benefits could be increased by increasing credit limits and flexibility in the use of loan proceeds, while reducing default rates and expanding program outreach.

Key words: Cameroon, credit, development, small farmers.

Operation Ceinture Verte (Green Belt Operation) is designed to accelerate the economic development of agriculture and improve the economic welfare of small farmers in Cameroon. The project has production, marketing, educational, and credit components (Cameroon, Ministere de l'Agriculture). In this report the focus is on the credit component of that part of the project designed to modernize plantain (vegetable banana) farms around Yaounde, the capital city.

Kamajou has estimated the annual net rate of return from the credit component of the plantain project to be 56% for society as a whole and 85% for the typical participating farmer. But the responsible government unit suffers a substantial loss even under conditions of mild default rates. There is an evident need to revise the sharing of costs and benefits so as to increase the viability of the program without unduly restraining net benefits to participating farmers. It is the objective of this article to report findings from a study of alternatives to achieve this goal.

The Problem

It is contended widely that capital shortages significantly constrain the economic development of small farms in developing countries. Cameroon is no exception. The remedy perceived in Cameroon, as in most developing countries, is to provide public sector loans to enable small farmers to modernize their production. Typically, the loans are made at concessionary rates of interest and so disbursed as to limit the borrower's use of loan proceeds; e.g., loans frequently are disbursed in kind or in coupons exchangeable for designated production inputs.

Credit, defined as capacity to borrow, can be exchanged by the farmer in a loan transacted with the lender with whom the credit is defined. As an alternative to borrowing, the farmer can reserve that credit, holding the reserve as a form of liquidity. If loans in the government credit program are restricted in use, reserved government credit has little liquidity value. However, if the loans can be used for unpredicted obligations, credit reserves do have liquidity value. They lessen the farmer's need to hoard gold, jewelry, and other liquid assets and allow him to commit more cash to production. They also lessen the farmer's dependence on the moneylender.

To have liquidity value, the credit must be perceived as available on a permanent basis and in predictable quantities and terms (Baker, Baker and Bhargava). Moreover, the proceeds must be usable over the whole range of expenditures faced by the small farmer (Singh). In contrast, the government's small farmer credit program often is perceived (all

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too accurately!) to be temporary, subject to changing rules, and restrictive in the use of the loan proceeds. Often, too, loan acquisitions are slow, costly, and bureaucratically cumbersome. A survey of participants reveals that the credit component of *Operation Ceinture Verte* shares many of these properties. Hence the credit it produces has limited liquidity value, is costly to administer, and is limited in outreach among small farmers.

Interest rates lower than lending costs restrict the outreach of the program and/or size of individual loans, drain resources from the public sector, and threaten the continuation of the credit program. It is this threat, as perceived by the borrowers, that induces a further incentive toward default. As default rates increase, they quickly become destructive to the lending program.

Viability of the lending program can be increased by raising interest rates and by lowering lending costs. The commercial loan alternative for the small farmer is the moneylender. The substantially higher rates charged by the moneylender allow a considerable rate increase available to the small farmer credit program before the borrower is diverted to the moneylender because of interest rate.

Modeling the Small Farm

To infer the on-farm effects of varying credit limits, interest rates, and other terms of loans, linear programming was used to model the small farm borrower, with data from a survey of participants in *Operation Ceinture Verte* (Kamajou). In addition to such technical data as resource endowments and production and cost coefficients, the small farm is modeled under a variety of conditions in its financial environment. Each depicts a policy position of the government credit program and responses to that position on the part of the small farmer. Data were obtained from secondary sources to supplement the survey data. The unit was modeled to be representative of small farms in the area covered by the survey (Kamajou).

Objective Function of the Model

The farmer is assumed to maximize the end-of-period net cash flow and, in some specifications, the value of cash and credit held in reserve. The end-of-period net cash flow is shown by the activity level of cash transfer to the objective function. The values of cash and credit reserves are determined by liquidity

Table 1. Model Constraints

Row Description	Constraint Relation	Constraint Level[a]
Cash requirements	E	(1)[b]
Cash supply (by season)	E	(2)[b]
Cash supply, end of period	E	0
Cash accounting equality (by season)	E	0
Cash reserve: 0,20,40,60,80(%) (by season)	E	0
Government credit (seasons 1, 3)	LE	(3)[b]
Government credit account (season 1, 3)	E	0
Government credit reserve: 0,20,40,60,80(%) (seasons 1, 3)	E	0
Moneylender credit limit (by season)	LE	(4)[b]
Moneylender credit account (by season)	E	0
Moneylender credit reserve: 0,20,40,60,80(%) (by season)	E	0
Commitment to plantain production	E	1
Plantain production requirement	E	0
Liquidity reserve requirement (by season)	GE	(5)[b]
Debt: Government plantain loan	E	0
Debt: Government cocoa loan	E	0
Debt: Moneylender loan (by season)	E	0

[a] All constraint levels stated in terms of CFAF; one CFAF = US $0.0042

	(1)000	(2)000	(3)000	(4)000	(5)000
[b] Season 1	10	20	160.8	15	20
2	8	5	—	25	15
3	15	15	18.4	2	25
4	15	25	—	1	25

valuation activities described later. Because the reserves do not product cash flows, their contributions to the value of the objective function must be subtracted from its total value to obtain net cash flow to the household.

Constraints of the Model

The study focuses on the financial environment of the producer with the constraints listed in table 1. Some of the family food needs are met with subsistence crops. Cash is required to buy food and pay for other living expenses, mainly schooling; clothing; health; and traditional, civil, or religious obligations. Seasonal variations (see note a, table 1) reflect differences in length of season as well as seasonal distribution of requirements.

Initial cash supplies also differ by season. A sum of 20,000 CFA francs (1 CFAF = US $0.0042), for example, is assumed available to the household on 15 March. Seasonal cash supplies are increased by sales, by interseason transfer, and by borrowing. Any cash surplus is transferred to the next season or, in the case of the last season, to the objective function. All available cash is allocated between the cash account and the cash reserve. From the cash account, cash is available for consumption, production, and debt payment. Cash in reserve is valued to reflect liquidity preferences. The percentages for reserved quantities allow for approximately nonlinear value functions (Baker and Bhargava).

Government credit also is specified by season. Government loans are disbursed for cocoa (with no interest charge) and for plantain (with a 6% interest charge) at the beginning of each planting season: March for season one and September for season two. Loan limits are set by the application rates per hectare for fertilizers, insecticides, and other inputs. The farmer is not required to borrow the total available.

Government credit is allocated between the government credit account and the government credit reserve. The government credit account is available for borrowing, which adds to the farmer's production assets or to cash, depending on the type of loan disbursement. The amount not borrowed is held in reserve. Government loans for plantain production require the producer to commit 14,000 CFAF to plantain. Therefore, the total value of the loan the farmer receives in kind is equal to his needs (as determined by the area farmed) minus 14,000 CFAF.

Lending limits (i.e., "credit") are assumed to be 25% of the borrower's net worth. The net worth itself is assumed to be approximately 50% of his gross annual money income, an estimate obtained by survey. Moneylender credit differs by season, as shown in the constraint levels in column 4 of the footnote of table 1.

Moneylender credit is allocated between moneylender credit account and moneylender credit reserve. Borrowing from the moneylender draws upon the moneylender credit account. Moneylender credit reserve constitutes a source of liquidity.

Liquidity requirements reflect needs to meet unexpected cash expenses or cash obligations despite adverse cash flows. They are functions of expected money income and are shown to vary among seasons (column 5) and to reflect the risk factors of each season (such as drought, epidemy, plant destruction by insects, prices for cash crops).

Borrowing creates debts which must be repaid or, if unpaid, carried over as liabilities. Debt balances are described in constraints differentiated by source and time of borrowing (government or moneylender), and use of loans, for government loans (plantain or cocoa).

Activities of the Model

Activities most relevant to financial aspects are listed in table 2, expressed in terms of activity units given in the last column. Some (though not all) of the activities related to production, marketing, and consumption are omitted.

Food requirements are expressed in terms of major nutrients or dietary requirements—protein, fat, iron, and vitamin A—and reflect safe levels of energy and nutrient intakes, as established by recent documents of the Food and Agricultural Organization of the United Nations (FAO). The outlays supplement food produced within the unit. Subtracting home-produced supplies from the (FAO) safe levels determines the balance to be met by purchasing. This balance is converted into actual weight of food and then stated in terms of cash requirement. The most expensive source among alternatives for each nutrient is chosen to calculate cash requirements for that nutrient cash need. Thus the model provides the

Table 2. Model Activities

Column Description	Unit
Buy protein items (by season)	kilograms
Buy fats items (by season)	kilograms
Buy iron items (by season)	milligrams
Buy vitamin A items (by season)	000 International Units
Meet other family living expenses (by season)	CFAF
Hire labor (by season)	man days
Buy fertilizer for plantain	CFAF[a]
Buy insecticide for plantain	CFAF[a]
Buy pesticide for plantain	CFAF[a]
Buy insecticide for cocoa	CFAF[a]
Buy fungicide for cocoa	CFAF[a]
Borrow from government for plantain (season 1, 3)	CFAF[a]
Borrow from government for cocoa	CFAF
Borrow from moneylender	CFAF
Commit cash to plantain	CFAF
Repay government (by season)	CFAF
Repay moneylender (by season)	CFAF
Allocate cash to cash account (by season) subject to reserve: 0,20,40,60,80 (%)	CFAF
Allocate government credit to government credit account (by season) subject to reserve: 0,20,40,60,80 (%)	CFAF
Allocate moneylender credit to moneylender credit account (by season) subject to reserve: 0,20,40,60,80 (%)	CFAF
Value reserved cash (by season): 0,20,40,60,80,100 (%)	CFAF
Value reserved government credit (by season): 0,20,40,60,80,100 (%)	CFAF
Value moneylender credit (by season): 0,20,40,60,80,100 (%)	CFAF
Transfer cash: between seasons and to objective function	CFAF

[a] In some specifications government loans are disbursed in kind.

household with flexibility in making up its daily diet. Other family living expenses are specified to be paid with cash.

Crop expenses also are specified to be paid with cash, except for models in which government loans are disbursed in kind. Hired labor is assumed identical to family labor in terms of quality and is paid with cash.

Borrowing activities are differentiated by source, use (in the case of government loans), and season. Government loans for plantain and for cocoa currently are disbursed in kind. Loans from the moneylender are assumed to be disbursed in cash at a 50% annual rate of interest. The moneylender is included in the model because informal lending in the rural and even in the urban milieu is an important part of the small farmer's financial environment. To qualify for a government plantain loan, the farmer must commit 14,000 CFAF in cash for every planting season. Hence, activities are specified that commit cash to plantain activities by planting season and thus to meet the qualification requirement.

Borrowing from either source reduces the level of the credit account of that particular source. Credit accounts of both government program and moneylender are reduced by one unit for each unit of borrowing. In addition, the credit programs interact. Moneylender credit is reduced by .50 CFAF when the farmer borrows one CFAF from the government. Government credit is reduced by one CFAF when the farmer borrows one CFAF from the moneylender.[1]

Finally, borrowing creates a debt. The debt repayment activities are differentiated by source of debt, use of borrowed funds (plantain and cocoa), and by season the debt is contracted. A debt is assumed contracted the first day of the borrowing season. The earliest repayment date is the first day of the following season. Repayment coefficients are calculated as one plus the interest due on one CFAF in the period of repayment.

Current policy provides for government loans to be disbursed in kind. However, in alternative models cash disbursement is substituted and input-purchasing activities specified. Comparing outcomes between models determines the effects of in-kind disbursement on the net cash flow of the small farmer, as well as on farm organization.

Cash used for cash requirements is drawn from cash accounts. Also, activities are specified that value reserved cash. The proportions of cash used and cash reserved must always add to one. The value of a CFAF of cash held in reserve is the reservation price the producer sets for cash to be committed to use, and is—at that price—what a unit of the cash reserve contributes to the objective function. The values of these cash reserves are given in footnote a, table 3. The value of a unit of cash in reserve increases as the percentage of cash held in reserve decreases. Every unit of re-

[1] These coefficients are chosen so as to reflect each lending agent's perception of ability to recover loans it disburses. The well known low repayment record of the government credit programs is reflected by a reduction of its loan as a response to the borrower's commitment to another lender. The private moneylender has enjoyed over the years a relatively high repayment record. Therefore, he reacts to the borrower's commitment to the public lender by reducing his credit availability by 50%.

served cash satisfies one unit of liquidity requirement.

Credit is an asset which the borrower allocates between a credit account and a credit reserve. The proportion allocated to credit account is used for borrowing, while the rest is kept in reserve. Credit allocation activities are specified just like the cash allocation activities. Credit allocation activities are specified for both government and moneylender credit.

Credit reserves are valued by season, by percentage of credit held in reserve, and, where relevant, by the source of credit. The procedures are the same as those for the valuation of cash reserves. The credit reservation prices differ from those of cash because of the difference between cash and credit as contributors to liquidity. (See footnote b, table 3.)

The differences in the reservation prices between government and moneylender credit reflect a judgment on the effects of restrictions on use of government loan proceeds and the perceived unreliability of government loans. Any surplus cash is transferred from the cash account of a given season to the cash account of the next. From the last season, cash is transferred to the objective function.

Results

Several models were specified, as indicated in table 3. In model 1, government loans are as-

Table 3. Specifications on Government and Moneylender Credit and on Reserve Values for Cash and Credit (see table 1 for initial limits set)

	Loans Disbursed in		Credit Reserves		Credit Limits		Interest Rate	
Model[a]	Kind	Cash	Not Valued	Valued[b]	Fixed	Varied[c]	Fixed (6%)	Varied (6%–36%, in intervals of 6%)
1	x		x		x		x	
2		x		x	x		x	
3		x		x		x	x	
4		x		x	x			x

[a] Cash reserves valued as in the following schedule, for models 1, 2, and 4:

Percent of Cash in Reserve	Value of One CFAF in Season 1	2	3	4
100	1.20	1.10	1.30	1.30
80	1.30	1.20	1.40	1.40
60	1.45	1.35	1.55	1.55
40	1.70	1.60	1.80	1.80
20	2.10	2.00	2.20	2.20

[b] Credit reserves valued as in the following schedule:

	Value of One CFAF in Season					
	1		2	3		4
Credit in Reserve (%)	Moneylender	Government	Moneylender	Moneylender	Government	Moneylender
100	.50	.40	.35	.60	.45	.60
80	.55	.50	.40	.75	.55	.75
60	.90	.75	.65	1.00	.85	1.00
40	1.35	1.15	1.10	1.45	1.30	1.45
20	1.60	1.45	1.30	1.70	1.55	1.70

[c] Changes in model 2 credit limits and associated changes in the cash and credit reservation values:

Items	Changes				
	(%)				
Credit limits	10	20	30	40	50
Cash reserve value	−10	−20	−30	−40	−50
Credit reserve value	+10	+20	+30	+40	+50

sumed to be disbursed in kind. In contrast, moneylender credit is available for loans disbursed in cash. In model 1, the concessionary interest rates and loan disbursed in kind lead the small farmer to question the viability of the government credit program and to perceive it as valueless in terms of credit reserve. Model 1 reflects the current situation. In model 2, the government is specified to disburse its funds in cash rather than in kind, thus allowing the producer to make choices among input mixes for his production processes. Flexibility in choices, made available by cash disbursement, elicits a liquidity valuation for reserved government credit. Reduced administrative costs also improve the prospects of program viability.

Models 3 and 4 are variations on model 2. Loan proceeds are in cash for both, and credit reserves are valued for government as well as for moneylender credit. In model 3, government credit limits are varied as shown in footnote c of table 3. Note also the associated changes in reserves values. Model 4 is the same as model 2, except that interest rates on government loans are varied, as indicated in the last column of table 3.

Liquidity Management and Producer Behavior

Results from model 1 are reported in the first column of table 4. They suggest outcomes to be expected if the government loans are disbursed in kind and at high net lending costs. One reason loans are disbursed in kind is to try to assure the use of loans for "productive" purposes. Comparing results from models 1 and 2 reveals that it is optimal for the farmer to produce in either case with highly intensive technology. Yet, survey observations revealed that the typical farmer uses somewhat less intensive technology, despite disbursements in kind. In sum, the choice of technology is largely independent of type of disbursement. The farmer will find a way to respond optimally to his options, whatever the form of loan disbursement.

Model 1 holds cash 404,674 CFAF in reserve. The size of the reserve depends on the cash reservation prices in relation to rates earned from cash committed to production. The value of the objective function, as generated by the model, includes the value of the liquid reserves (cash and moneylender credit). The value reported in table 4 (679,352 CFAF) reflects a reduction for the value of reserves. If the cash held in reserve is added to the net cash flow, the total comes to 1,084,026 CFAF.

In model 2, reserved government credit is valued at reservation prices shown in footnote b of table 3. The prices are used to value government credit reserve in the objective function, just as cash reservation prices were used to value cash in reserve. Model 2 lessens borrowing from both government and moneylender, increasing cash committed to production and leaving the production organization unchanged from model 1.

Model 2 generates the same optimal production activities as model 1. Government borrowing is reduced to 169,418 CFAF (122,531 from a plantain loan and 46,787 from a cocoa loan) and borrowing from the moneylender to 15,000 CFAF. Cash held in reserve is reduced to 301,019 CFAF.

Committing more cash and near-cash assets to production is an important social, as well as private, contribution and reduces the burden on the government in its attempts to generate more funds for loans. Note that in model 2 the net cash flow increases to 756,753 CFAF. Added to cash in reserve, the total comes to 1,057,771 CFAF, nearly the same as produced by model 1. In model 2, the farmer is more secure than in model 1, owing to a considerably greater reserve in credit.

Effects of Credit Limit (Model 3)

The theory of liquidity management suggests an inverse relationship between the reservation prices of cash and the amount of cash committed to productive use. When credit limits are increased, the value of cash in reserve is decreased. The change in cash reservation price schedule, associated with the increased credit limits, is shown in footnote c, table 3. The associated increase in the credit reservation prices also are shown.

The results are summarized in table 4. The increase in government credit limits does not affect the production organization found optimal under specifications of model 2. However, after a 30% increase in the loan limits, the producer ceases to borrow from the moneylender. The increase in government credit limits considerably reduces the amount of cash held in reserve, releasing it for production activities. Credit limits and the allowable use of loan proceeds are important factors in reducing the small farmer's reliance upon the mon-

Table 4. Optimal Activity Levels for Models 1–3

Activity	Model 1	Model 2	Model 3: Increments to Government Credit Limit of Model 2 (%)					Unit
			10	20	30	40	50	
Produce plantain	1.00	1.00	1.00	1.00	1.00	1.00	1.00	hectare
Produce cocoa	2.54	2.54	2.54	2.54	2.54	2.54	2.54	hectare
Produce subsistence crops	2.17	2.17	2.17	2.17	2.17	2.17	2.17	hectare
Buy fertilizer for plantain	750.00[a]	750.00	750.00	750.00	750.00	750.00	750.00	kilogram
Buy insecticide for plantain	69.30[a]	69:30	69.30	69.30	69:30	69.30	69.30	kilogram
Buy pesticide for plantain	10.87[a]	10.87	10.87	10.87	10.87	10.87	10.87	kilogram
Buy insecticide for cocoa	30.48[a]	30.48	30.48	30.48	30.48	30.48	30.48	kilogram
Buy fungicide for cocoa	508.00	508.00	508.00	508.00	508.00	508.00	508.00	sack
Hire labor	217.06	217.06	217.06	217.06	217.06	217.06	217.06	man-day
Loan from government								
Plantain	130,000	122,631	176,880	192,960	192,960	192,960	192,960	CFAF[a]
Cocoa	46,787	46,787	46,787	46,787	46,787	46,787	46,787	CFAF
Loan from moneylender	25,000	15,000	8,500	6,241	0	0	0	CFAF
Reserves								
Cash	404,674	301,019	282,094	263,198	244,304	225,409	206,515	CFAF
Government credit		38,169	54,985	71,802	88,619	25,436	22,253	CFAF
Moneylender credit	45,000	24,474	33,920	33,368	32,815	32,263	31,711	CFAF
Net cash flow	679,352	756,753	764,198	771,644	779,088	786,534	793,950	CFAF
Net cash flow and cash reserve	1,084,026	1,057,772	1,046,292	1,034,842	1,023,392	1,011,943	1,000,465	CFAF

[a] Disbursed in kind in model 1.

eylender and in freeing some of the cash "trapped" for liquidity needs for use in production activities. Both results are vitally important for all government credit programs for small farmers.

It is of interest to note the increased net cash flow as the government loan limit is increased. On the other hand, the amount of cash reserved diminishes. The net cash flow and cash reserved are summed in the last row of table 4. The sum is shown to diminish slightly as the government loan limit increases. The behavior of this sum is influenced by reservation prices assumed for cash and for credit. Little empirical evidence is available on reservation prices. Logic strongly supports the assumptions made on reservation prices in response to reserved levels of either cash or credit. The assumptions made on reservation prices of cash in relation to credit are perhaps less certain.

Effects of Higher Interest Rates for Government Loans (Model 4)

Model 4 is the same as model 2, except the government interest rate is permitted to vary from the current 6% (as in model 2) to 36%, by five equal increments of 6%. Results are reported in table 5. Until the interest rate reaches 24%, few changes occur in the optimal solution. Land use, intensity of input use, and borrowing activities remain unchanged. There is a slight reduction in labor hired.

At interest rates above 24%, changes occur in crop mix and technology. At 30%, the producer reduces cocoa production and fertilizer intensity in plantain production: 0.87 hectares of plantain are produced with high fertilizer use and 0.13 with medium fertilizer use. Increasing the cost of borrowing shifts the production mix from the capital intensive technology, but the total area in plantain is unchanged. At 36%, the shift of plantain toward lower technology continues. So does the reduction in cocoa production. However, there is a 12% increase in land used for plantain. Hired labor increases as interest rates increase beyond 24%. The shift in technology, however, occurs only after the interest rate is raised above 24%.

Changes also occur in financial organization. While the size of cocoa loan remains unchanged (as does the amount borrowed from the moneylender), the size of plantain loan diminishes as the interest rate is increased beyond 12%.

Cash reserves diminish for the increment, 6% to 12%, and again for the increment, 24% to 30%. In contrast, reservations of moneylender credit increase for the increment, 6% to 12%, and diminish for the increment, 30% to 36%. The diminution in net flow is surprisingly slight over the range of increase in interest rates, and the size of cash reserve varies little. Hence the total of net cash flow plus cash reserve is little affected by the wide range of interest rates.

Summary and Conclusions

Relaxing restrictions on the use of government loan proceeds is beneficial in terms of output and income. Liquidity needs force the farmer to reserve large amounts of cash and credit for adverse contingencies. A reliable source of credit, with flexibility in use of loan proceeds, allows him to increase his production commitment of cash and its equivalents otherwise reserved to respond to risk.

Disbursements in cash also reduce administrative costs in lending, adding to perceived viability of the government lending agency. Comparing the results of models 2 and 4 reveals that credit limits are far more important in improving the farmer's income than is the rate of interest he pays. A 400% increase in the rate of interest (from 6% to 30%) reduces the farmer's income by about 2%, while a 50% increase in the loan limits increases his income by about 20%. Higher interest rates would provide the lending agency with resources that could be used to strengthen its performance.

While not demonstrated in the programming results, there are persuasive reasons to suppose that incentives to default also would be lessened. The larger and more certain credit supply, along with increased flexibility in use of loan proceeds, would add to the value of government credit, making it more worthwhile to the farmer to protect it.

These findings were confirmed largely by results of the field survey. Asked about interest rate, size of loans, flexibility in use of loan proceeds, and the length of time for loan disbursement, 37% of the farmers interviewed ranked the flexible use of loan funds as most important, 31% chose the rapid disbursement of funds, 27% chose the size of loan, and only 5% chose the level of interest rate as a major factor in their borrowing decision.

Table 5. Activity Levels in Optimal Solutions of Model 4

	Interest Rate on Government Loans: Plantain and Cocoa (%)					
Activity	6	12	24	30	36	Unit
Produce plantain: A[a]	1.00	1.00	1.00	0.87	0.75	hectare
Produce plantain: B[b]	0	0	0	0.13	0.37	hectare
Produce cocoa	2.54	2.54	2.54	2.32	2.31	hectare
Produce subsistence crops	2.17	2.17	2.17	2.17	2.17	hectare
Buy fertilizer for plantain	750.00	750.00	750.00	818.60	783.70	kilogram
Buy insecticide for plantain	69.30	69.30	69.30	76.23	63.20	kilogram
Buy pesticide for plantain	10.87	10.87	10.87	13.03	13.03	kilogram
Buy insecticide for cocoa	30.48	30.48	30.48	27.84	27.84	kilogram
Buy fungicide for cocoa	508.00	508.00	508.00	464.00	464.00	sack
Hire labor	183.04	182.00	163.16	190.24	195.17	man-day
Plantain loan from government	160,800	160,800	150,318	132,480	145,231	CFAF
Cocoa loan from government	46,787	46,787	46,787	46,787	46,787	CFAF
Loan from moneylender	15,000	15,000	15,000	15,000	15,000	CFAF
Reserve cash	300,988	297,131	297,131	289,425	289,124	CFAF
Reserve government credit	38,169	38,169	38,169	38,169	38,169	CFAF
Reserve moneylender credit	24,474	24,474	24,474	24,474	24,474	CFAF
Net cash flow	756,588	754,132	752,319	751,480	750,807	CFAF
Net cash flow and cash reserve	1,057,576	1,051,263	1,049,450	1,040,906	1,039,931	CFAF

[a] High intensity fertilizer use.
[b] Moderate intensity fertilizer use.

In Cameroon, as in many other developing countries, formal financing of small farmers is mainly from the public sector. Many current government agricultural credit programs for small farmers are performing poorly. Criteria for success or for evaluating credit policies are several and diverse: (*a*) lending costs (including default costs), (*b*) the number of farmers served (the outreach of the program); (*c*) the degree to which the farmer's financial needs are met, including risk bearing and the average size of loans made available; (*d*) increase in farmer's output, income, or welfare; and (*e*) impact on income distribution between various farm groups.

High administrative costs and low repayment records together with low interest rates produce prohibitively high net costs. In spite of attempts to justify the low rates of interest, it remains that they contribute to a misallocation of resources, the weakening and the distortion of capital markets, reduced incentives to save, and costly, nonproductive forms of liquidity management (Gonzales-Vega, Donald, Osuntogun). Moreover, the high net costs severely restrict the outreach of the programs.

In terms of criteria (*c*) and (*d*), results from this research suggest that performance could be improved by offsetting increases in interest rates with higher loan limits, and by reducing costs associated with restricting uses allowed for loan proceeds. An interest rate of 18%–24% has been suggested by various sources (e.g., Donald). This range in essence was confirmed by the results of this study. The higher interest rate would increase the feasibility of a savings program. Mobilizing rural savings would broaden the institutional resource base. The research did not address criterion (*e*) directly. However, by increasing program outreach, the suggested reforms would lessen the inequities now current because of the restricted scope of the program.

The project, *Operation Ceinture Verte*, has increased the participating farmer's output and income substantially. In terms of the other criteria, the results are less satisfactory. The

program exhibits excessive and perhaps prohibitive costs. Two major reasons account for these excessive costs: (*a*) the program does not charge its customers for the full cost of services rendered; (*b*) the administration of such small credit schemes requires a large amount of supervision. Lending in kind complicates the problem still further. The high default rate seems likely to be due in part to the low value the borrower ascribes to the loan program's credit. Finally, only a small proportion of small farmers are reached by this program, owing largely to its high net costs.

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References

Baker, C. B. "Role of Credit in the Economic Development of the Small Farm Agriculture." *Spring Review of Small Farmer Credit*, vol. 19, pp. 41–70. Washington, D.C.: USAID, 1973.

Baker, C. B., and V. Bhargava. "Financing Small Farmer Development in India." *Aust. J. Agr. Econ.* 18(1974):101–18.

Banque Nationale pour le Developpement Agricole (BNDA). "Prets de Soudure." *Spring Review of Small Farmer Credit*, vol. 6. Washington, D.C.: USAID, 1973.

Cameroon, Ministère de l'Agriculture. *Operation Ceinture Verte. Project de Creation aux environs de Yaounde des Plantations Villageoises de Bananier-Plantain.* Yaounda, July 1973.

Donald, Gordon. *Credit for Small Farmers in Developing Countries*. Boulder, Colo.: Western Press, 1975.

Gonzalez-Vega, C. "Interest Rate Policies and Small Farmer Credit Programs in LDC's." *Spring Review of Small Farmer Credit*, vol. 19, pp. 335–72. Washington, D.C.: USAID, 1973.

Kamajou, F. "Government Financing of the Development of Small Farm Agriculture in Center-South Province of Cameroon." Ph.D. thesis, University of Illinois, 1978.

Osuntogun, A. "Some Policy Considerations in the Execution of Public Agricultural Credit Schemes in West Africa." *West African J. Agr. Econ.* 11(1973).

Singh, I. J. "The Need for Flexibility in Small Farmer Credit Programs." *Spring Review of Small Farmer Credit*, vol. 19, pp. 421–44. Washington, D.C.: USAID, 1973.

Notes

Fungibility and the Design and Evaluation of Agricultural Credit Projects

J. D. Von Pischke and Dale W Adams

Agricultural credit is an important element in development efforts in most low income countries. Some countries such as India, Brazil, and Thailand assign credit a leading role in rural development. The World Bank, the Inter-American Development Bank, and the Agency for International Development have aggressively promoted agricultural credit, committing in excess of $5 billion through hundreds of projects. The popularity of credit is due in part to the notions that loans are necessary to accelerate technological change in farming and that formal credit is required to release peasants from dependence on moneylenders. In certain situations the relative ease with which credit projects can be initiated adds to their appeal.

Most credit projects are aimed at stimulating the production of commodities such as rice or dairy products, augmenting the use of an input like fertilizer or improved breeding stock, encouraging investment in machinery and irrigation, or providing more financial services to target groups such as the rural poor, cooperative members, or corn producers. Agricultural banks, cooperative banks, credit unions, and supervised credit agencies have been created under some of these projects. Other projects have augmented loanable funds flowing through existing parts of rural financial markets (RFMs).

A number of these projects have been evaluated formally.[1] Major measures of performance emphasized by donor agencies are disbursement of project funds and recovery rates on loans to farmers. Most evaluations also attempt to measure the impact of loans on farm activities. Impact is usually expressed in terms of increases in crop area or yields financed by the project and by the quantity of animals, fertilizer, or tractors bought with loans. Numbers, amounts, and kinds of loans made, and farm income and net worth are also used as performance measures. These evaluations typically include little analysis in depth of the credit institutions handling project funds.

While project evaluations may show slow loan disbursement or loan repayment problems, they often indicate that production, input use, investment, and target group participation goals were generally met, and that projects achieve many of their objectives. Despite this, a number of observers are increasingly concerned about the quality and quantity of services provided in low income countries by rural credit institutions and by the RFMs of which they are a part. Critics charge that although donor funding for agricultural credit has increased substantially, the real value of total agricultural loans has decreased in many countries, that concessionary loans often end up in the hands of the well-to-do, that loans for agricultural purposes are diverted to nonagricultural uses, that policies in many RFMs encourage consumption and discourage savings, that the term structure of agricultural loans often contracts or fails to expand, and that RFMs are adopting few cost-decreasing technologies in the provision of financial services. It is disconcerting that rural financial markets could perform poorly while projects within these markets are judged to be doing well. An attempt is made in the following discussion to resolve this paradox by showing how design and evaluation procedures which ignore fungibility lead to faulty conclusions about agricultural credit project results.[2]

Fungibility, Additionality, Substitution, and Diversion

Fungibility is a prime characteristic of modern currency. Standardization, or interchangeability, enables money to serve as a *numéraire* and medium of exchange, and makes monetized transactions more efficient than barter. Fungibility underlies the role of money in efficient resource allocation in classical economic models and in increasing monopoly ac-

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[1] Only a few of these evaluations are available in published form (e.g., Adams, Giles, Pena; Daines). Some overview publications, however, do give a flavor of project results (Agency for International Development, Donald, Food and Agriculture Organization, Kratoska, Reserve Bank of India, Shaw, World Bank, 1975, 1975–79).

[2] Fungible: "of such a kind or nature that one specimen or part may be used in place of another specimen or equal part. . . . ; interchangeable." (*Webster's New Collegiate Dictionary*. Springfield, Mass., 1973.)

cumulation in Marxist models. This important quality of finance may cause difficulties when it is not understood, when efforts are made to limit exchange by the imposition of controls, and when channels through which funds are directed prove too small to accommodate the desired flow. Agricultural credit project design and evaluation often encounter these problems.

Fungibility makes credit activities hard to evaluate. Its effects appear at the national level, the credit agency level, and the farm level. Reasons given to justify a loan at any of these levels may or may not be related to the activities stimulated at the margin by the additional liquidity a loan provides. At the farm level, for example, many credit projects treat loans as if they were production inputs, ignoring the fact that a unit of borrowed money is identical to other units of money held by the borrower. Even if a loan is given in kind, such as bags of fertilizer, the goods provided can often be sold and converted into cash if the borrower desires (Scobie and Franklin). For all practical purposes, loans in cash or kind can be used to buy any good or service available to the borrower in the market.

Additionality, substitution, and diversion are terms that clarify the problems fungibility poses for credit projects. Additionality is jargon for the changes created by a project: it is the difference between the with and without project situations. It is generally assumed, for example, that a donor-funded credit project should induce the borrowing country to increase loans to farmers by an amount at least equal to the donor's loan. At the RFM level, credit for target purposes should expand by an amount at least equal to the project funds provided. Likewise, it is expected that farmers will increase their input purchases and investments by amounts comparable to the loans they receive and augment production of goods promoted by the project.

Measuring additionality is difficult because it is impossible to know exactly what governments, lenders, and farmer borrowers would have done in the absence of a credit project. To what extent would the government have allocated more funds to agricultural credit without project assistance? Would credit institutions have channelled funds away from other activities to serve project objectives in the absence of a project? Would borrowers have used cash from their own reserves or informal credit sources, or reduced their consumption, to fund an activity without a project? In other words, to what degree do project funds simply substitute for other resources which would have been used, in any event, for project purposes?

Diversion is a more extreme form of substitution. Diversion occurs, for example, when a farmer obtains a cattle loan but does not buy any cattle and uses the funds for a purpose not authorized by the loan contract. It is usually difficult for lenders, governments, and project personnel to divert credit project funds unless donors are lax in supervising projects, or unless the administration and accounting systems used by project agencies are faulty. Close supervision of thousands of rural borrowers, however, can be a costly task, and diversion occurs even in well-administered programs.

Changes in the purchasing power of money further complicate analysis of additionality. While nominal amounts of loans and farmer expenditures may expand in the desired direction, the real value of loans may remain constant or decline as inflation erodes the purchasing power of financial instruments.

The three synthetic case studies that follow illustrate the difficulties of measuring the impact of credit projects. The case studies illustrate analytical problems arising at the three different levels from fungibility, additionality, substitution, and diversion. Following the case studies, some suggestions are presented for improving the design and evaluation of credit projects.

A Farm Household in Africa

Mrs. Kariuki is an African farmer who recently received a loan for the purchase of three milk cows and other materials needed to establish a dairy operation. The amount of the loan was $1,200, divided as follows on the loan contract: three milk cows, $800; fencing, $200; a water tank, $100; and a milking shed, $100.[3] She went into debt because of the easy terms offered (80% financing, five years to repay, 10% interest) and the range of attractive investment opportunities available in her locality. Many of her neighbors are expanding their dairy and tea enterprises, and several have entered the transport business. Land prices are increasing, and many families are improving their homes.

Mrs. Kariuki is an attractive credit risk because her family's farm is productive and well-maintained. In addition to the 10-acre farm owned by her husband, she owns an urban lot which she used as loan collateral. She has $600 in her Post Office savings account, which, in conformity with local traditions, was not disclosed on her loan application.

Mrs. Kariuki used the funds borrowed to obtain the goods specified in her loan agreement. Her loan was disbursed by the lender, out of funds supplied by a donor agency, against invoices submitted directly by the suppliers from whom Mrs. Kariuki obtained the improved dairy cows and materials. But, the $100 worth of iron sheets and lumber for the milking shed were not used to build a shed, which in the local community would be considered ostentatious. Rather, they were used to extend and reroof the familiy's house. In addition to the loan proceeds, Mrs. Kariuki invested $300 of her funds

[3] For consistency, all values in the three cases are expressed in a common currency.

n the dairy project to help purchase the cattle and ›ther investment goods, to pay for labor to install he fencing and water tank, and to transport loan-inanced items to the farm.

Mrs. Kariuki's first investment priority was to :stablish a dairy enterprise because of its expected ›rofitability and steady labor demands and the famiy's preference for fresh milk. Just before the loan vas approved, she sold her entire herd of five in'erior dairy animals for $800 in cash. She obtained :redit for the purchase of new stock and materials :ven though she could have financed most of the ›roject out of the sale of the five cows and the $600 n her savings account.

Her other priorities include planting more tea, which requires hired labor; acquisition of more and; and joining her husband and some friends in purchasing a taxi so that their community would be inked more dependably with a market town 12 niles away. Reflecting these priorities, Mrs. Kariuki spent $250 for tea planting and $300 to purchase a half acre from an elderly neighbor after receiving the dairy loan. In addition, Mrs. Kariuki's family decided to increase consumption expenditures by $100. Part of this went to buy a new coat for her husband and two new school uniforms for her children, while the remainder financed a visit to relatives. Of her $1,400 in cash and in the post office savings bank, $450 remained after these expenditures. Since she wanted to keep $200 on hand for a rainy day, this left $250 for investment in a share of a taxi.

The conventional project interpretation assumes that Mrs. Kariuki's loan financed a dairy enterprise establishment. Therefore, the impact of the loan is assumed equal to changes in Mrs. Kariuki's dairy enterprise. This approach ignores changes in consumption and adjustments in all other uses and sources of household liquidity associated with the loan. It overlooks the fact that Mrs. Kariuki substituted fungible loan funds for a part of the investment in dairying, which she would have undertaken in any event because dairying was her highest priority. It also fails to take into account that Mrs. Kariuki diverted iron sheets and timber to house improvement rather than using these materials for a milking shed.

In contrast to the conventional project evaluation approach, a financial view of Mrs. Kariuki's activities would take a broader perspective that the loan gave her liquidity—an increase in her general command over resources. Because of fungibility, a financial view does not attempt to relate the loan to just one use of liquidity. The impact of the loan can be found only in the marginal changes in all sources and uses of household funds which resulted from the additional liquidity provided by the loan. Obviously, the type of information needed to document these liquidity flows for a representative sample of farm households is very time-consuming and costly to collect.

A Credit Agency in Asia

The effects of fungibility also are found at the level of agencies lending to farmers. The institutions involved in the following hypothetical example from an Asian country are a diversified local lender called the Farmers Small Enterprise Bank (FSEB), a central rediscounting agency (CRA) which uses donor and government funds to make loans to lenders like FSEB, and a donor agency which helped design the project. The main objective of the project is to increase the volume of loans to small farmers.

The mechanics of the credit project are as follows: the target group consists of farmers with less than two hectares of land. CRA advances $0.80 for every $1.00 lenders extend to the target group. The interest rate on CRA loans to lenders is 4%, while the lenders charge farmer borrowers 10% per annum. CRA, in turn, claims from the donor agency 75% of its advances under the project, and obtains the other 25% from the national treasury. The project supports an important national credit priority, which is also reflected in Central Bank regulations, favoring agriculture. One of these is that at least 20% of the outstanding loans of each bank must consist of agricultural loans, while banks like FSEB which are located in farming communities must devote 40% of their loan portfolios to agricultural activities.

The effect of the project on lender behavior is illustrated by FSEB's plans and actions before and after the project. Before the project in 1978, FSEB directors developed a sources-and-uses-of-funds budget for 1979. As shown in table 1, the major source in the original 1979 budget was loan repayments received from borrowers. The allocation of new loans was budgeted to ensure compliance with the requirement that 40% of total loan balances on the books are farm loans, and FSEB directors expected that new loans of $750,000 to these borrowers would meet this target. The directors also expected an increase in deposits at their bank because of a recent increase in interest rates paid on savings from 5% to 6% per annum. The directors allocated a portion of the expected deposit increase to non-interest-bearing reserves held with the Central Bank, and to liquidity reserves in the form of government bonds and cash required to support the expanded level of deposits.

Shortly after FSEB directors approved the 1979 budget, the general manager was visited by representatives of the donor agency and CRA, who informed him that the FSEB could participate in the small farmer credit project. The general manager later presented to his board a revised budget assuming FSEB participation in the project (table 1). In presenting the revised budget, the manager noted that about $300,000 of the $750,000 in loans to farmers in the original budget met the credit project's lending criteria. FSEB could discount with

Table 1. Projected Sources and Uses of Funds by the Farmers Small Enterprise Bank (FSEB) in 1979

Sources of Funds		Uses of Funds	
Original budget	($ thousand)		($ thousand)
Loan repayment from borrowers	1,500	Increase in statutory reserves (25% of increase in deposits)	75
Increase in deposit liabilities	300	Increase in cash and government securities held	25
Net profit	50	New loans made:	
		Farmers	750
		Others	1,000
Total	1,850	Total	1,850
Revised budget			
Loan repayment from borrowers	1,500	Increase in statutory reserves (25% of increase in deposits)	50
CRA rediscount of project loans	240	Increase in cash and government securities held	40
Increase in deposit liabilities	200	New loans made:	
Net profit	55	Farmers	755
		Others	1,150
Total	1,995	Total	1,995

CRA 80% of the $300,000 and gain $240,000 in loanable funds. The manager proposed to his board that $15,000 of these additional funds be used to buy more high-yielding government securities (9% per annum), and that $150,000 be used in loans to landlords and businessmen in the area who could offer substantial collateral. He recommended that FSEB roll back its interest rates paid on savings from 6% to 5%, in order to reduce projected increases in deposit liabilities from $300,000 to $200,000 in 1979. The addition of project resources to the previous deposit target would cause FSEB to fall below the minimum capital-to-assets ratio required by the Central Bank. Because the revised budget would increase FSEB net profits by 10%, it was approved by the board. Late in 1979 the manager reported to the board that budget targets were substantially achieved.

The net result of FSEB participation in the new loan program was a decrease in local deposit mobilization, lower rates of return to all depositors, an increase in government securities held by the bank, and an increase in the amount of money loaned to borrowers other than the project's target group. The project resulted in only a small amount of additional lending to the target group. Substitution washed out almost all of the intended effects of the project in this particular lender's activities.

A Latin American Country

From 1960 to 1978, a Latin American country received $80 million in ten loans or grants from donor agencies for agricultural credit projects. These credit projects had four objectives. First, four projects established institutions to serve rural areas: a supervised credit program, an agricultural cooperative bank, rediscount facilities for agricultural loans at the Central Bank, and private finance agencies to provide risk capital for agricultural enterprises. Second, all ten projects provided funds to expand agricultural credit supply. Third, seven of the projects aimed at expanding the amount and number of loans to the rural poor. Fourth, three projects sought to provide more medium- and long-term loans to farmers.

All ten projects have been evaluated. Several had loan recovery problems which undermined at least one of the new institutions. Analysis of loan applications and interviews with loan officers and borrowers indicate that objectives regarding type of borrower, enterprise, inputs, and loan term structure were largely met. Overall, these evaluations suggest the projects did a surprisingly good job of achieving their goals. One donor was sufficiently satisfied with its projects to give the country an additional loan of $15 million to expand medium- and long-term lending to small farmers. During 1979, the loan was disbursed for the purposes intended. An evaluation gave a glowing report of the results.

Despite these projects, farmers, and especially small farmers, continued to complain about the shortage of loans. As a result, one of the donors engaged consultants to prepare another sizable agricultural credit loan proposal. A financial analyst on the consulting team was asked to assess the performance of the country's financial markets. He did not take a conventional project focus in his analysis, but examined imports, the government budget, and overall RFM performance. He rea-

soned that changes in activities associated with the most recent loan would be the best indicator of what might be expected from the next loan.

The analyst collected information on imports, as presented in table 2. Agricultural investment goods imported increased by $15 million in 1979. Because of inflation in world prices, however, the real value of these imports in 1978 prices declined from $200 million in 1978 to $195 million in 1979. At the same time the real value of imports of nonagricultural investment goods and government and defense goods increased. Military hardware and supplies to furnish new tourist hotels accounted for most of the real increases in imports. From these figures the analyst concluded that the 1979 agricultural loan relaxed the country's foreign exchange constraint and that arms for the military and bathtubs and toilets for new hotels were the main result.

The analyst then reviewed the 1979 government budget. What he found is also shown in table 2. The government increased the nominal amount allocated for agricultural programs from $250 million in 1978 to $265 million in 1979. The government met the conditions of the agricultural loan agreement by adding to the Agricultural Bank's loan portfolio the $15 million generated by sales of goods imported under the loan. But because of domestic inflation the real amount in 1978 prices allocated to agriculture decreased from $250 million in 1978 to $241 million in 1979, despite the donor's loan. Real increases in the 1979 budget for defense, nonagricultural development, and general expenses reflected government priorities. From these data the analyst concluded that the government budget was not influenced in the desired direction by the agricultural credit project.

The analyst next looked at activities in formal rural financial markets in the country, and collected the data presented in table 3. The nominal amount of new agricultural loans made each year increased from $50 to $144 million between 1960 and 1980. In real terms, however, the amount of purchasing power represented by the formal agricultural loan portfolio peaked in 1975 and declined by about 5% through 1980. The $94 million increase in the nominal amount of new agricultural loans made annually from 1960 to 1980 can be explained largely by the $95 million in foreign grants and loans for agricultural credit, given the average term structure of approximately one year. The analyst concluded that foreign funds substituted for at least some local funds which would have been allocated to agricultural credit in the absence of external assistance.

The analyst was disappointed to see that ratios of agricultural credit to total credit and agricultural credit to GNP from agriculture declined after 1970. In spite of heavy emphasis by donors on expanding agricultural credit during the 1970s in the country, it appears they were unable to effect structural changes in credit allocation in favor of agriculture. Furthermore, the decline in the deposit to loan ratio after 1970 shows that some portions of RFMs were becoming more, rather than less, dependent on outside resources.

Table 3 shows no increase after 1970 in the proportion of farmers who received credit: over the twenty-year period, levels of access were not significantly altered. Most of the increase in agricultural credit apparently went into large loans for experienced borrowers. Because agricultural lenders' records did not include details on borrowers' economic characteristics, the analyst could not

Table 2. Imports and Government Budget Allocation before and after an Agricultural Credit Loan to a Latin American Country

Imports	1978 (Current Prices)	1979 (Current Prices)	1979 (In 1978 Prices)[a]
Agricultural investment goods	200	215	195
Nonagricultural investment goods	300	360	327
Intermediate goods	100	110	100
Consumption goods	100	110	100
Government and defense goods	300	350	318
Other	100	110	100
Total	1,100	1,255	1,140
Government Budget Allocation			
Defense	1,000	1,200	1,091
Health, education, welfare	1,000	1,100	1,000
Agricultural development	250	265	241
Nonagricultural development	300	350	318
General government expenses	300	340	309
Other	100	110	100
Total	2,950	3,365	3,059

[a] Reflects adjustment for an inflation rate of 10% during calendar year 1979.

Table 3. Measures of Rural Financial Market Performance in a Latin American Country 1960–80

Year	Total Value of New Loans Made to Agriculture: Current Value	Total Value of New Loans Made to Agriculture: In 1960 Prices	Ratio of Agr. Credit / Total Credit	Ratio of Agr. Credit / Agr. GNP	Ratio of Deposits to Loans in RFM[a]	Percentage of Farmers Receiving Formal Loans	Avg. Term Structure of Agr. Loans
	($ thousand)						(months)
1960	50	50	.09	.21	.14	15	10
1965	70	69	.10	.24	.16	16	12
1970	90	88	.12	.27	.18	17	15
1975	110	104	.11	.26	.17	15	14
1978	115	100	.10	.24	.17	14	13
1979	130	99	.09	.23	.16	13	12
1980	144	99	.08	.21	.16	12	11

[a] Excludes commercial banks

document loan allocation by economic class: small loans do not necessarily go to low income borrowers, and a wealthy borrower may have multiple loans. He did find, however, that those agencies serving mainly the rural poor had modest real increases in their loan portfolios from 1970 to 1980, while agencies lending mainly to high income borrowers expanded substantially.

Finally, the analyst concluded that the credit projects of the 1970s were associated with a trend towards shorter average agricultural loan term structures. While in 1970 the average loan matured in fifteen months, in 1980 the corresponding term was only eleven months. Between 1978 and 1980, this average dropped from thirteen to eleven months, despite the two- to five-year loans under the $15 million 1979 project. Funds from medium- and long-term loans which matured outside that project were reloaned at shorter maturities.

In his report the financial analyst argued that fungibility and substitution had substantially diluted the intended impact of the eleven credit projects, especially the 1979 project. While the 1979 loan did relax the foreign exchange constraint, it was associated with additional imports of military and tourist hotel hardware. It was not accompanied by a net increase in real imports of agricultural investment goods, and it did not reverse the trend towards shorter average term structures of formal agricultural loans. Because of inflation and concessionary interest rates to farmers, the flow of external resources for agricultural credit failed to maintain, let alone increase, the purchasing power of the formal agricultural portfolio. There is little evidence that the rural poor received much additional funding, despite the emphasis in various credit projects on expanding financial services for this target group. It also appeared that donor funds accounted for virtually the entire nominal increase in agricultural credit.

Recommendations

At the farm level it is very costly, if not impossible, to determine the impact of credit. At the national and lender levels, many countries provide an ideal environment for substitution and diversion to flourish. This environment is created by distorted exchange rates, balance of payments problems, rigid interest rate policies, and substantial inflation coupled with negative real rates of interest. Because of these facts, we feel that it is necessary to alter the traditional design of credit projects and also to modify substantially the way they are evaluated. Several different approaches, used singly or in combination at the project, sector, and national levels, might be taken to diminish the extent to which RFM performance varies from project objectives.

Three points must be recognized in order to understand the approaches and to effect the changes we propose. The first is that loans provide additional liquidity, which tends to flow toward the most attractive use available from the perspective of the loan recipient. The second is that credit project impact, elusive at the farm level, should be viewed in the context of RFM performance. The third is that the major determinants of the financial situations at the farm and RFM level which credit projects seek to ameliorate are not necessarily most effectively tackled on a project basis alone, but rather reflect policies which repress RFM development.

At the project level it is vital to view loans as additional liquidity rather than as farm inputs. This would force project designers to be more sensitive to the alternatives available to those with access to additional liquidity. For example, if a credit project were designed to stimulate cotton production in Northern Colombia, designers ought to be aware of the returns available in the area to production of

marijuana. Likewise, credit for "productive" purposes will be used for consumption if family members are hungry or lack profitable investment alternatives. Only after it can be shown that target activities are among the more profitable or satisfying uses of additional liquidity can it be concluded that a major part of the liquidity provided by the loan will be used as projected.

Farm activities receive primary emphasis in the traditional credit project. The strategy we propose would be centered on the performance of institutions responsible for project implementation, based on the assumption that target groups are most effectively benefitted when institutions serving them are efficient, strong, and independent. This perspective is perhaps more consistent with concerns for local participation and control than the traditional project approach, since implementing agencies have to relate to local circumstances in order to be successful. The traditional format finds justification in tons of grain or increases in farm incomes without necessarily having to come to grips with the vitality of RFM intermediaries. Projects which undermine the vitality and financial integrity of a credit agency should not be termed successes.

In addition, specific additionality requirements stated in real terms might be written into a project. Any such targets should apply to the entire RFM. For example, if a project objective is to lend to 5,000 new small borrowers through a supervised credit program, the 4,000 borrowers transferred to the supervised credit agency from the agricultural bank should not count toward this requirement. Progress toward additionality targets can be measured at the national and credit agency levels, although such requirements could raise problems of data reliability and create incentives for evasion if not carefully designed.

Because of fungibility, project design and evaluation should consider rural financial market performance in general. For example, if an agricultural credit project is aimed at supplying more medium- and long-term credit, project design should include an assessment of why the RFM is not adequately providing this type of financial service. Once this deficiency is explained, the designers of the project should show how the project will induce the RFM to offer a service which it is presently unable or unwilling to provide.

At the national level, credit projects usually result in more direct government participation in RFMs. Various rationing schemes are typically part of this involvement. Because of fungibility, finance is difficult to control. Direct attempts to gain control are usually costly, often fail to achieve stated objectives, and generally result in secondary effects that are unexpected—the worst possible development for planners (Kane, McKinnon, Schatz, Shaw). We feel that the best intervention is often indirect. Attempting to tackle problems in RFMs at the project level or through individual institutions may be less fruitful than use of the price system to encourage priority activities and to discourage less useful ones. Experiences from the application of this strategy suggest that many of the problems associated with RFMs respond favorably to flexible interest rate policies supported by other measures designed to increase competition in finance. This approach accommodates fungibility and encourages resource reallocation by enabling financial markets to function more efficiently.

In sum, we feel that because of fungibility the focus of project design and evaluation should shift away from the traditional emphasis accorded the demand side of farm credit. A better perspective on farm credit would incorporate attention to important variables on the supply side which are reflected in the performance of lenders in RFMs. Less emphasis should be given to evaluating the impact of credit use at the farm level, and more emphasis placed on how intervention in RFMs affects lender behavior, lender vitality, and the overall operation of RFMs. Less time should be spent measuring what is virtually impossible to measure. More attention should be accorded those things which can be documented.

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References

Adams, D. W, A. Giles, and R. Pena. "Supervised Credit in Colombia's Agrarian Reform: An Evaluative Study." Mimeographed (No. 40). Centro Interamericano de Reforma Agraria, Bogotá, Colombia, 1966.

Agency for International Development. *A.I.D. Spring Review of Small Farmer Credit*. Washington, D.C., 1973.

Daines, S. R. *Guatemala: Analysis of the Impact of Small Farmer Credit on Income, Employment and Food Production*. Washington, D.C.: Agency for International Development, Div. Sectorial Analysis, Latin American Bureau, 1975.

Donald, G. *Credit for Small Farmers in Developing Countries*. Boulder, Colo.: Westview Press, 1976.

Food and Agriculture Organization (FAO). *World Conference on Credit for Farmers in Developing Countries*. Rome, 1975.

Kane, E. J. "Good Intentions and Unintended Evil." *J. Money, Credit and Banking* 9(1977):55–69.

Kratoska, P. H. *The Chettiar and the Yeoman*. Singapore: Institute of Southeast Asian Studies Occ. Pap. No. 32, 1975.

McKinnon, R. J. *Money and Capital in Economic Development*. Washington, D.C.: The Brookings Institution, 1973.

Reserve Bank of India. *Report of the All-India Rural Credit Review Committee*. Bombay, 1969.

Schatz, S. P. *Economics, Politics and Administration in Government Lending: The Regional Loans Boards of*

A Simulation Study of Maximum Feasible Farm Debt Burdens by Farm Type

Gregory D. Hanson and Jerry L. Thompson

Financial leverage, which magnifies the effect of farm income instability upon "bottom line" profitability, becomes less feasible as income fluctuation increases. The combination of wide fluctuations in income coupled with heavy debt-servicing commitments can render the farm insolvent, imperiling continued survival. Determining how much debt a given farm can service is therefore a matter of considerable importance.

Studies that have explored the effects of income variability upon debt usage have for the most part focused upon one or limited farm types. Few have attempted to identify maximum feasible debt burdens consistent with continued survival of the firm. In an analysis of Ohio dairy farms, Falls found that changes in interest rates had only slight effect upon maximum feasible debt levels and also that large dairy farms could sustain greater debt-to-asset (D/A) ratios than small farms. Wehrly and Atkinson estimated that dairy-hog farms could service debt loads ranging from 46% to 60% of assets, depending upon farm size and ability of the farm family to "live frugally." Patrick and Eisgruber found that managerial ability and long-term loan limits were the most important factors influencing farm growth; while Boehlje and White determined that maximization of net worth requires heavy debt loads. Finally, Baker has proposed to index land payments to farm prices and yields in a model including amortization insurance and a mandatory debt reserve.

Research Objectives

This paper probes the question of how much debt could have been maintained successfully by farm types in southern Minnesota 1966–75. Because it is the low return years that pose the real threat to debt-servicing ability, a financial leverage strategy that attempts to maintain the maximum amount of debt (as a percentage of assets) that can be safely carried in low return years will present no debt payment difficulties in high return years.

With this perspective in mind, the approach was to (*a*) obtain yearly estimates of enterprise cash flow rates of return;[1] (*b*) to estimate annual cash income for representative farms of specified asset size and enterprise types, and relate this to consumption, taxes, and debt service demands on cash income; (*c*) to identify the maximim feasible debt ratio (MFDR, i.e., maximum "safe" total debt divided by total assets) for farm types under strict and more lenient loan-servicing conditions; (*d*) to explore the sensitivity of MFDRs to changes in rates of return earned on assets, enterprise diversification, and farm size.

For the third item, two levels of satisfactory debt service were defined: (*a*) all principal and interest payments made strictly as scheduled, (*b*) a two-year deferment on non-real estate loan principal payments. The latter comparatively lenient and perhaps more realistic condition permits deferral of non-real estate loan principal payments in a year of low income, provided that at the end of the following two years, additional interest and principal payments are made so that all originally scheduled loan servicing is once again on a current basis.

Under this flexible condition, a bad year followed by two strong years will support more debt by "averaging" returns across three years. Usually the farmer tends to work more closely with the short-term lender and it may prove to be less difficult for the farmer to defer short-term than mortgage debt. In view of this, two-year deferral of non-real estate debt was chosen as a conservative yet flexible form of finance assistance.

The Data

Farm records for 1966–75 were examined. The records are for members of the allied farm management associations in southern Minnesota. Association members are generally full-time farmers. While these farmers may be somewhat above average in managerial ability, their farms are of average size (459 acres in 1975) for the region. Approximately

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[1] The cash flow *ROR* is not strictly "cash flow," because it includes adjustments for crop and livestock inventory changes. It is actually net working capital generated by the farm operation.

250 individual farm records were analyzed per year. Less than 4% of the completed association records were excluded from the data base due to either lack of sufficient detail or farm record error. Farmland was priced at estimated current county-wide average values (based upon annual surveys). Finally, earnings and expenses on a total farm basis with no division between operator and landlord shares were used.

The Model

In this study, a multiple linear regression was used to estimate rates of return by farm enterprise. In the regression model, the sum of the weighted enterprise returns is equated with the total farm cash flow rate of return (*ROR*). The model is

$$(1) \qquad ROR_{jt} = \sum_{i=1}^{I} r_{it}\, w_{ijt} + \epsilon_{it},$$

for enterprises, $i = 1, 2 \ldots I$; farms, $j = 1, 2 \ldots J$; and years, $t = 1, 2 \ldots T$. (ROR_{jt}) is farm cash income in year t divided by total farm assets; cash income equals the sum of enterprise values added plus miscellaneous income less operating expenses; (r_{it}) is the average rate of return on enterprise i in year t; (w_{ijt}) is value added for enterprise i in year t divided by the farm's total value added in year t. Value added consists of cash sales less purchases plus adjustments for inventory change and transfers between enterprises. Operating expense includes purchases of nonbreeding livestock, feed, crop expense, livestock expense, real estate tax, and hired labor. Miscellaneous income consists of work for other farmers, patronage refunds, and other such items.

Equation (1) was estimated for both cash flow and accrual income rates of return for each of the ten years. It represents an attempt to "decompose" the observed whole farm rate of return into a linear sum of enterprise rates of return. By relating the farm *ROR* to the observable value-added-by-enterprise variables, regression coefficients can be interpreted as enterprise rates of return if the fraction of a farm's total resources invested in an enterprise is proportional to the fraction of total farm value added that originates in the respective enterprise. This is a strong assumption that may warrant empirical verification. In the present framework, value-added weights serve as instrumental variables for the unobserved fractions of total farm assets invested in each enterprise. (Alternatively, this approach can be viewed as a means to control for variations in enterprise composition of mixed enterprise farms.)

With this assumption, the farm is treated as a "portfolio" of hog, dairy, beef-feeding, and cash crop enterprises. By using the estimated enterprise weights, we can control large variations in the relative importance of, for example, beef-feeding versus hog-finishing activities that likely characterize the farm records.[2]

Finally, and somewhat more complex, specifications of equation (1) were tested for the existence of size and enterprise interaction effects on cash flow *ROR*s. However, no consistent, significant size and/or interaction effects existed in the sample (Hanson and Thompson).

Debt Structure

Because farm debt was not broken down into current, intermediate term, and real estate categories in the records; debt composition by maturity type (with the exception of seasonal debt) was posited to be proportional to asset composition by length of asset life. That is, the proportion of farm type k's total debt in the form of mortgages in year t is equal to the ratio of real estate to total assets for farm type k in year t, etc. Decomposition of farm assets into current, noncurrent chattel, and real estate assets, by enterprise, also was carried out with regressions analogous to equation (1).

Because the farm records also did not provide sufficient detail for seasonal expenses, seasonal debt by farm type was estimated from the Census of Agriculture (Allen, p. 9, and U.S. Department of Commerce).

Determining Maximum Feasible Debt Ratios

To avoid financial distress, annual cash inflows must meet or exceed consumption expenses, taxes, debt service obligations, and cash operating expenses. That is (see Hanson and Thompson),

$$(2) \quad \begin{array}{c}\textit{Gross}\\ \textit{Cash Flow}\end{array} \geq \begin{array}{c}\textit{Minimal}\\ \textit{Household}\\ \textit{Expenditures}\end{array} + \begin{array}{c}\textit{Marginal}\\ \textit{Consumption}\end{array}$$
$$+ \begin{array}{c}\textit{Nonfinanced}\\ \textit{Operating}\\ \textit{Expense}\end{array} + \begin{array}{c}\textit{Interest}\\ \textit{Expense}\end{array} + \begin{array}{c}\textit{Debt}\\ \textit{Principal}\\ \textit{Expense}\end{array}$$
$$+ \begin{array}{c}\textit{Income}\\ \textit{Social Security}\\ \textit{Taxes}\end{array} + \begin{array}{c}\textit{Seasonal}\\ \textit{Debt}\\ \textit{Repayment}\end{array}$$

Seasonal debt repayment is a programming device to enforce short-term borrowing to be less than or equal to operating expenses. Consumption consists of a large minimum family living allowance and a linear marginal propensity to consume of .097 (estimated farm records). Effective (semilog) tax rate functions were estimated from aggregate tax data for married persons filing jointly. The effective tax rate (estimate) was then appled to accrual income after interest payments to compute total

[2] One beef feeding-complete program hogs farm type has been defined where each enterprise provides at least 20% of sales and both enterprises account for more than 80% of all sales. In this scheme, either enterprise may substantially dominate total sales.

taxes. The current interest rate is an annual average of southern Minnesota Production Credit Association interest rates; the intermediate term rate is a five-year average of PCA loan rates. The real estate mortgage is assumed to be in the third year of a twenty-year term; five-year average St. Paul Federal Land Bank interest rates were used (all rates adjusted for stock purchase requirements).

Thus, estimated gross cash inflows must equal or exceed estimated gross cash outflows. It was assumed that excess cash generated in high return years was used to expand assets and that no cash reserve or loan prepayment reserve existed. Also, off-farm income was not available for the full-time operators analyzed in this study.[3] While the absolute level of debt typically will expand in the years immediately following a deferral of principal payments (in proportion to the increases in reported assets), it was assumed that such increases in the absolute amount of the farm unit's debt was used entirely to finance acquisition of new assets and not to repay the deferral. That is, absolute debt may increase in response to increases in assets, but the amount of debt relative to assets remains constant at the MFDR level determined for the low income year.

Once repayment assumption, deferral status, enterprise types, and enterprise weights have been initially set, MFDRs are discovered through an iteration technique that solves equation (2) as an equality. This is done by increasing or decreasing the debt ratio (D/A) until cash available for debt service is exhausted. The process is applied for each farm type for each of the ten years in the sample period; however, only the maximum debt ratios in the low return or "critical" year are reported.

As indicated above, size and variability of enterprise rates of return, covariation of enterprise rates of return (as reflected in the whole farm *ROR* for two-enterprise farm types) and enterprise weights (the elements of portfolio risk) are processed to generate MFDRs. The reader may note that risk is evaluated implicitly by looking at debt-servicing ability in low income years. Downside variability (from trend) is of crucial concern in this analysis; and the MFDR approach effectively distinguishes upside from downside income variability. An example of this in the present study will be complete program hog earnings, which, although highly variable, support high debt burdens because of the upside nature of their income variability.

[3] Farmers, in the aggregate, do hold financial assets that could serve as a cash reserve (Penson). We believe it is realistic to assume no such holdings exist for farm operations pressing the limits of their debt carrying capability. (This viewpoint is supported by the experiences of extension fieldmen for the farm management associations.) The absence of a cash reserve in the model is consistent with recognition that infrequent use of the Federal Land Banks' cash-reserve option results from borrowers obtaining higher returns by investing excess funds in the farm operation (Baker, p. 2).

The Results

The employment of historical production returns data in a simulation approach facilitates examination of a rich variety of questions while subscribing to a reality that does not abstract from changing weather conditions, deviations from optima, or other such factors.

Cash Income Variability by Farm Type

Cash income from dairy operations exhibited the least annual variability while obtaining the median income ($34,340) among the nine farm types of table 1. Beef-feeding and cash grain enterprises were each characterized by both large income variability and low average incomes. However, in combination, these two enterprises accomplished much of what is intended by an ideal diversification scheme. The relatively high cash grain and beef-feeding coefficients of variation, .478 and .475, re-

Table 1. Cash Income Variability and Rate of Return (*ROR*) by Farm Type 1966–75

Farm Type[a]	Coefficient of Variability[b]	Mean Cash Income *ROR*	High Annual Cash Income *ROR*	Low Annual Cash Income *ROR*	Mean Cash Income ($)
Dairy	.181	.15	.19	.09	34,340
Cash grain-beef feeding	.259	.11	.18	.08	26,965
Dairy-complete program hogs	.325	.16	.29	.13	39,918
Beef feeding-complete program hogs	.391	.15	.25	.11	35,677
Cash grain-complete program hogs	.430	.15	.30	.09	36,784
Complete program hogs	.463	.18	.38	.11	45,497
Beef feeding	.475	.11	.16	.01	25,858
Cash grain	.478	.11	.22	.07	28,071
Hog finishing	.956	.11	.25	−.02	24,763

[a] Two enterprise farms are comprised of equal value-added shares per enterprise.
[b] Coefficient of variability = standard error around the linear trend divided by the mean.

spectively, are almost halved to .259 in the combination of cash grain-beef-feeding operation; while average cash income stays essentially the same $26,965 (as against $28,071 and $25,858 for cash grain and beef feeding, respectively). Because hog finishing had a much greater income variability than cash grain-beef feeding, the latter farm type could successfully service a much higher level of debt (even though both farm types experienced the same average rate of return of all).

Effects of Farm Size and Debt Repayment Flexibility on Debt Capacity

The ability to defer debt principal payments affected debt capacity more than increases in farm size (this is partly due to the fact that we found no significant large-scale cash flow rate-of-return effects in the sample). To analyze size effects on debt, alternative size farm units were developed from the record data. Small, medium, and large farms are defined, respectively, as farms with assets equal to 25th, 50th, and 75th percentile of sample assets. Two enterprise farms derive 50% of total value added from each enterprise. Estimated asset size of small farms ranged from $109,000 in 1966 to $325,000 in 1975; similarly, from $148,000 to $478,000 for medium-size farms, and from $206,000 to $681,000 for large-size farms.

When debt service obligations are required to be fulfilled as scheduled (table 2A), among the small farm types only dairy-complete program hogs could sustain an MFDR greater than 40%. Among large-size farms, only complete program hogs and dairy-complete program hogs sustained more debt than equity. While the annual flow of income from complete program hogs was much less stable than that of dairy (table 1), the lowest returns year for dairy (1975) provided less debt capacity than the poorest returns year for farrow-to-finish hogs (1967).

Comparison of MFDRs with the more flexible and realistic two-year debt deferral condition (table 2B) versus the no-deferral condition (table 2A) reveals dramatic increases in debt capacity for all farm types except those with a cash grain or dairy enterprise. (Because 1976–77 farm record data were not available for this study, the flexible credit debt ratios for 1974 and 1975 are based upon estimated cash flow for the years 1976–77, projected from growth trends in the data.) Comparison by farm size under the flexible default condition (table 2B) reveals that medium-size operations supported MFDRs substantially higher than small-size operations (by about 10%). However, the increase in maximum debt ratios accompanying an increase in farm size from medium to large was less, about 7%. Finally, observe that a small farm with two-year permissible debt deferral typically could sustain proportionally as much debt as a large farm with no debt deferral permitted (table 2B, column 1 versus table 2A, column 3). Only MFDRs under the two-year deferral repayment condition are presented in following sections.

Effect of Enterprise Diversification on Debt Capacity

The importance of enterprise selection to maximum debt levels is illustrated in table 3. The left-hand percentage in each column heading of table 3 indicates the enterprise share of the first farm enterprise listed in the far left, "farm type," column. For example, a farm type that obtains 75% of its value added from cash grain production and 25% from dairy production has an MFDR of .376 (column 2).

Perhaps the most interesting trend in the MFDRs is that, while the largest debt ratios in each farm-type row tend to occur in the one-enterprise columns (columns 1, 5), in seven of the nine farm types the maximum debt ratios for evenly diver-

Table 2A. Sensitivity of Maximum Feasible Debt Ratios to Farm Type and Farm Size; No Deferral of Loan Payments Allowed

Farm Type	Critical Year	Farm Size[a] Small	Medium	Large
		(1)	(2)	(3)
Cash grain	1967	.098	.228	.330
Dairy	1975	.348	.414	.455
Beef feeding	1974	0.0	0.0	0.0
Complete program hogs	1967	.356	.471	.560
Hog finishing	1974	0.0	0.0	0.0
Beef feeding-complete program hogs	1974	.316	.403	.468
Cash grain-beef feeding	1967	.220	.351	.452
Cash grain-complete program hogs	1967	.232	.355	.450
Dairy-complete program hogs	1967	.41	.51	.588

[a] Small, medium, and large-sized farms are defined, respectively, as farms with assets equal to 25th, 50th, and 75th percentile sample assets. Two enterprise farms derive 50% of total value-added from each enterprise.

Table 2B. Sensitivity of Maximum Feasible Debt Ratios to Farm Type and Farm Size; Two-Year Deferral of Non-Real Estate Loan Payments Allowed

Farm Type	Critical Year	Farm Size Small	Medium	Large
		(1)	(2)	(3)
Cash grain	1967	.147	.282	.376
Dairy	1974	.477[a]	.554	.57
Beef feeding	1974	.283	.362	.403
Complete program hogs	1967	.652	.770	.803[b]
Hog finishing	1974	.150	.222	.258
Beef feeding-complete program hogs	1974	.565[a]	.665	.707
Cash grain-beef feeding	1967	.301	.435	.526
Cash grain-complete program hogs	1967	.415	.542	.625
Dairy-complete program hogs	1967	.555	.652	.723

[a] Critical year is 1967.
[b] Limitation on current debt in effect.

sified farm types are in the upper half of the row range. For example, for the evenly diversified beef feeding-complete program hogs, the MFDR of .665 is markedly closer to the row's highest debt ratio of .77 than to the lowest of .362 (column 3 versus columns 5, 1). Thus, it can be argued that if diversification is undertaken to increase the feasibility of debt leverage and there is a large degree of uncertainty as to which of the selected enterprises may be most profitable, it may best be accomplished by dividing resources equally among enterprises.

Effect of Management Ability on Debt Capacity

Improvement in managerial ability (demonstrated by a 2%–4% increase in rate of return to assets) increased debt capacity significantly. To explore the influence of management ability on debt capacity, cash flow rates of return estimated from sample records were varied upward and downward from the yearly average. Resultant MFDRs are presented in table 4, where a 1% increase above the average cash income return to assets usually permitted an increase in maximum debt ratios of 5% to 7% (column 4 versus 3). This increase is about equal to that associated with increasing farm size from medium to large (table 2B, columns 3 versus 2). The 4% rate-of-return increase (table 4, column 5 versus 1) enables cash grain, beef feeding, hog finishing, and cash grain-beef feeding to double or triple debt loads. Finally, observe that medium-size farms with a 2% superior earnings (table 4, column 5) have markedly higher MFDRs than large farms with average earnings (table 2B, column 3). This demonstrates the importance of farm management skills to successful debt leverage.

Validation

With the exception of hog-finishing operations, the standard errors of the enterprise rate-of-return coefficients (table 1) are generally quite low. The

Table 3. Sensitivity of Maximum Feasible Debt Ratios to Enterprise Mix, Medium-Sized Farms; Two-Year Deferral of Non-Real Estate Loan Payments Allowed

Farm Type	Critical Year	Enterprise Mix 100/0	75/25	50/50	25/75	0/100
		(1)	(2)	(3)	(4)	(5)
Cash grain-dairy	1967	.282	.376	.452	.514	.554[a]
Cash grain-beef feeding	1967	.282	.358	.435	.447	.362[a]
Cash grain-complete program hogs	1967	.282	.417	.542	.659	.770
Cash grain-hog finishing	1967	.282	.322	.358	.329[a]	.222[a]
Dairy-beef feeding	1974	.554	.513	.484	.429	.362
Dairy-complete program hogs	1967	.554[a]	.610	.658	.711	.770
Dairy-hog finishing	1974	.554	.450	.415	.323	.222
Beef feeding-complete program hogs	1974	.362	.517	.665	.731[b]	.770[b]
Beef feeding-hog finishing	1974	.362	.323	.287	.254	.222

[a] Critical year, 1974.
[b] Critical year, 1967.

Table 4. Sensitivity of Maximum Feasible Debt Ratios to Rate of Return on Assets on Medium-Sized Farms; Two-Year Deferral of Non-Real Estate Loan Payments Allowed

		Rate of Return on Assets				
Farm Type[a]	Critical Year	−2%	−1%	Historical Sample Average	+1	+2
		(1)	(2)	(3)	(4)	(5)
Cash grain	1967	.134	.209	.282	.355	.421
Dairy	1975	.467	.511	.555	.597	.639
Beef feeding	1974	.224	.293	.362	.430	.499
Complete program hogs	1967	.643	.707	.77	.81[b]	.829[b]
Hog finishing	1974	.01	.161	.222	.283[c]	.343[c]
Beef feeding-complete program hogs	1974	.533	.599	.665	.731	.768[b]
Cash grain-beef feeding	1967	.289	.362	.435	.507	.578
Cash grain-complete program hogs	1967	.406	.474	.542	.609	.676
Dairy-complete program hogs	1967	.547	.603	.652	.712	.766

[a] Two-enterprise farms derive 50% of total value added from each enterprise.
[b] Limitation on current debt in effect.
[c] Critical year, 1974.

average and largest standard errors (in parentheses) for each enterprise during the ten-year study are cash grain .007 (.009), dairy .007 (.010), complete program hogs .010 (.015), beef feeding .013 (.021), hog finishing .035 (.053).

Except for the regression relationship, the model employed primarily accounting identities. A limited number of farm management specialists and agricultural lenders were asked to evaluate this study's rate of return and MFDR estimates against their own experiences. They found the results "reasonable." For example, three of four loan officers interviewed ranked farm types by lender preference. A rank correlation test found their ranking positively correlated with this study's at a significance level less than .02.

Conclusion

Within the framework of this study, a flexible repayment agreement was found to be generally essential for heavy reliance upon debt financing. With a flexible repayment agreement and with land valued at current prices, substantial debt use was feasible for many farm types in the years 1966–75. Management ability appeared to have a greater influence upon debt capacity than farm size. Debt-servicing ability was improved more by becoming a good manager than simply by becoming a large operator.

Farms with a labor-intensive livestock component sustained the highest maximum debt ratios (generally by wide margins). If past trends continue, this indicates that a beginning farmer may have great difficulty financing a cash grain operation, while a labor-intensive dairy-complete program hog operation may prove to be an especially attractive entry-level farm type. Study findings lead us to stress the role of farm type as possibly the most basic variable in the successful use of farm credit when limited equity financing is available. That is, MFDRs differed substantially by farm type. It has been our impression, however, that some farm lenders (while agreeing that debt usage differences by farm type exist) have been reluctant to quantify or clearly differentiate maximum "safe" debt usage on the basis of the enterprise mix. While the actual values of MFDRs estimated may not be of particular interest to analysts outside the agricultural region examined, the relative financial strength of the farm types analyzed (or ranking) may be of interest, especially as related to changes in such key economic variables as equity funds available, farm size, the power of flexible credit arrangements, management improvement, and others.

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References

Allen, P. T. *Revision of USDA Non-Real Estate Farm Debt Series, 1967–75.* USDA ERS-647, Jan. 1977.

Baker, C. B. "A Variable Amortization Plan to Manage Farm Mortgage Risks." *Agr. Finan. Rev.* 36(1967): 1–6.

Boehlje, Michael D., and T. Kelley White. "A Production-Investment Decision Model of Farm Firm Growth." *Amer. J. Agr. Econ.* 51(1969):546–63.

Falls, S. D. "Farm Firm Debt Capacity: An Empirical Study of Northeastern Ohio Dairy Farms." M.S. thesis, Ohio State University, 1972.

Hanson, Gregory D., and Jerry L. Thompson. *Maximum Feasible Farm Debt by Farm Type.* Dep. Agr. and Appl. Econ. Staff Pap. P78-79, University of Minnesota, July 1978.

Patrick, George F., and Ludwig M. Eisgruber. "The Impact of Managerial Ability and Capital Structure on

Growth of the Farm Firm." *Amer. J. Agr. Econ.* 50(1968):491–506.

Penson, John B., Jr. "Toward an Aggregative Measure of Saving and Capital Finance for U.S. Farm Operator Families." *Amer. J. Agr. Econ.* 59(1977):49–60.

U.S. Department of Commerce, Bureau of Census. *Area Report–Minnesota*, vol. 1, part 15, Washington, D.C., Apr. 1972; *1969 Farm Finance, Special Reports*, vol. 5, part II, Washington, D.C., Aug. 1974.

Wehrly, J. D., and J. H. Atkinson. *Debt Load Capacity of Farms*. Purdue University Agr. Exp. Sta. Res. Bull. No. 780, June 1964.

Choosing Optimum Application Rates in Developing Countries

Philippe Savoie and Michel Kabay

The introduction of new varieties or of new cultivation techniques should be preceded by thorough agronomic research and economic analysis. This preparation is particularly necessary in developing countries, where peasants are rightfully conservative. Because they often barely manage with the food they produce, they are little inclined to take risks. They may try new varieties or techniques if they do not involve much capital outlay, but they will quickly abandon the innovations if they appear no better than the older techniques or varieties.

A rational approach to agricultural intensification in developing countries should start with precise characterization of plant performance not only in experimental plots but also in the peasants' fields. Once enough experimental data become available, these should be translated into continuous response functions, which are more convenient for analysis (Heady and Dillon).

These production functions help establish optimum levels of application rates for various such inputs as seed density, manure fertilizer, and pesticide rates. Because of the variability of plant response, these optima should be defined with confidence limits, to permit evaluation of risks to the farmers. Ideally, these levels can be estimated for individual farmers according to their personal preferences and attitudes toward risk (Dillon; Anderson, Dillon, Hardaker). Dillon and Scandizzo have shown how risk aversion or preference can be gauged in a peasant economy. In practice, however, we usually are faced with time and money constraints that prevent us from measuring preferences and estimating optimum production levels on an individual basis (Moscardi and de Janvry). The degree of unreliability inherent in such efforts may also deter such tedious work. Anderson, Dillon, and Hardaker point out that in many cases preferences are unknown and it may be more useful to establish a set of alternatives.

Using agronomic data, simple statistics, and elementary economic theory, this paper presents a method for optimizing application rates and for estimating the probability of success (or failure) in implementing new techniques in a peasant economy. An example using the seed density of Saxa dwarf beans in Rwanda (Camerman) is presented; the same method could be applied to other crops and treatments such as fertilizers and pesticides.

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Agronomic Model

Assuming a quadratic production function and a single variable input, we may define the yield increase per unit treatment as follows:

$$(1) \qquad Y = \frac{Y_T - c}{X} = a + bX,$$

where Y is yield increase per unit of X, usually in kilograms per kilogram (kg./kg.); Y_T is total yield (kg./ha.); c is the control yield (kg./ha.), when $X = 0$; X is the amount of treatment (kg./ha.); and a and b are, respectively, the Y intercept and the regression coefficient, estimated for the specific crop and the specific treatment. The variable Y varies linearly with treatment. The slope (b) is negative for most agronomic treatments, because yield increases are greatest at low application rates and decline in relative terms with increased application. Given sufficiently detailed agronomic information, it may be possible to apply linear regression analysis to compute confidence limits for predicted specific yields at various treatment levels.

Economic Analysis

We now consider profit as the value of total yield minus the cost of the treatment. From this statement and equation (1), maximum profit is seen to occur at

$$(2) \qquad X_{opt} = \frac{(V_t/V_y) - a}{2b},$$

where X_{opt} is the optimal level of X for maximum profit; V_t is the cost of the treatment in francs per kilogram (FR./kg); V_y is the cash value of the crop (FR./kg.). This optimum would be correct if the coefficients of the regression equation could be established without error. The intrinsic variability of biological materials requires statistical analysis to give confidence limits for X_{opt}. The width of the confidence interval will depend on the validity of the linear model and on the intrinsic variability of the plants.

Statistical Methods

A preliminary analysis of linear regressions of yield per unit seed of Saxa dwarf beans (kilograms of harvest/kilogram of seed) on seed density (kg./ha.) in four growing seasons showed significant differences among the equations fitted to the seasons ($F = 21582$, with three and sixteen degrees of freedom). (See Sokal and Rohlf, p. 450.) Considering the seasonal fluctuations as part of the fundamental variability of the system, we computed the analysis of variance with regression and found the highly significant regression equation

$$\hat{Y} = 33.9962 - 0.1830\,X, \tag{3}$$

where $\hat{Y}$ is the predicted yield per unit seed (kg./kg.) and X is the seed density (kg./ha.).

Table 1 shows the 95% confidence limits for predicted future yields, which were estimated using standard methods. The standard error of prediction was calculated in our example for individual farmers, not for farmers as a group, thus widening somewhat the confidence limits.

Using costs of twenty-five francs per kilogram for seed and fifteen for yield, we calculated the profit for each level of seed density and the lower and upper bounds and expected yields as

$$P = 15YX - 25X, \tag{4}$$

where P is profit in francs per hectare (FR./ha.).

Figure 1 shows these values plotted against seed density. Several strategies can be adopted, depending on which curve is used for decision. For example, if it is desired to maximize the minimum likely yield, a seed density of about 40 kg./ha. should be chosen. If a density of 90 kg./ha. is used, expected profit is maximized, but the probability of loss would be increased.

Table 1. Ninety-five Percent Confidence Limits for Predicted Yields for One Field in a New Season

	Yield per Unit of Seed (kg./kg.)		
Density	Lower Bound	Expected	Upper Bound
10	11.458	32.166	52.874
20	9.948	30.336	50.724
30	8.399	28.506	48.613
40	6.808	26.676	46.544
50	5.173	24.846	44.518
60	3.495	23.016	42.537
70	1.771	21.185	40.600
80	0.000	19.355	38.710
90		17.525	36.867
100		15.695	35.070
110		13.865	33.319
120		12.035	31.615
130		10.205	29.955
140		8.375	28.399
150		6.545	26.766
160		4.715	25.233

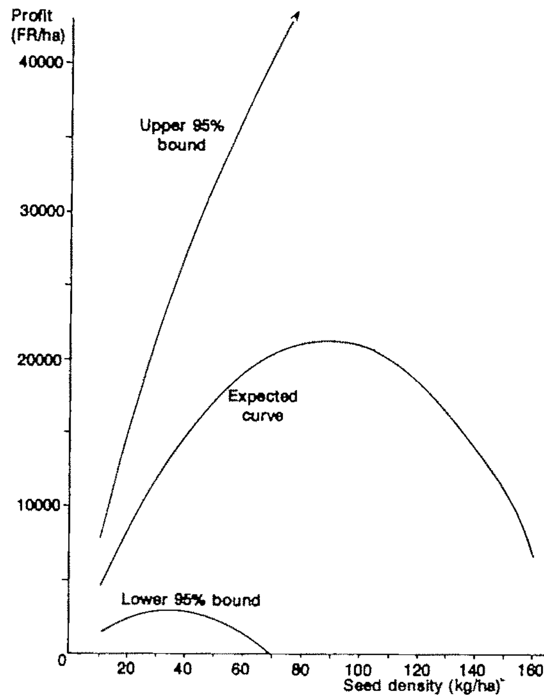

Figure 1. Profit versus seed density

What would the probability be of various profits at 90 kg./ha.? Applying the confidence interval formula to equation (4), we have

$$P_c = 15(\hat{Y} + t_{\alpha\beta}\, s_{\hat{Y}})X - 25X, \tag{5}$$

where P_c is the critical profit (FR./ha.), $t_{\alpha/2}$ is the one-tail t critical value with ν degrees of freedom, and $s_{\hat{Y}}$ is the standard error of prediction in a new test situation. For a given value of t, we have the cumulative probability of observing a profit greater than P_c. Figure 2 shows cumulative probability curves for seed densities equal to 40, 90, and 140 kg./ha.

Consider the curve for a seed density of 90 kg./ha. from figure 2. The probability of a net loss is about 5% (compared to less than 1% when density

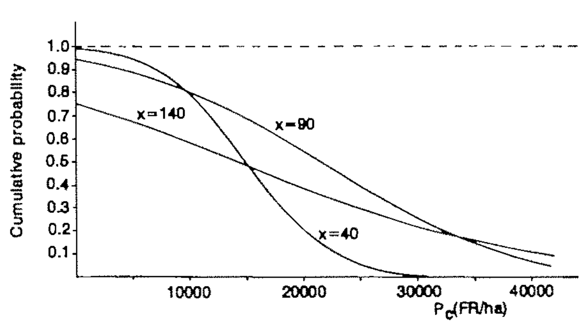

Figure 2. Probability of observing a profit greater than critical profit P_c

is 40 kg./ha. and about 25% when density is 140 kg./ha.). The probability of getting a greater profit than the maximum lower 95% confidence bound at 40 kg./ha. (where maximum profit was about 3,100 FR./ha.) is 92%. The probability of exceeding the expected profit at 40 kg./ha. of 15,005 FR./ha. using 90 kg./ha. is 69%. Also, the probability is about 71% that profit at 90 kg./ha. will be greater than the expected profit at 140 kg./ha., which is 14,087 FR./ha.

Other curves could be drawn for various levels of seed density. Based on the expected profit of a seed density of 60 kg./ha., a seed density of 90 kg./ha. is seen to yield a better profit, with a 56% probability. Compared against 80 kg./ha., a seed density of 90 kg./ha. would yield a better profit, with a 52% probability. As the distance between the optimum level and the actual practice decreases, improvements due to implementation of the optimum become less apparent.

Conclusions

We have applied elementary statistical and economic methods to optimize seed density of Saxa dwarf beans in Rwanda, using available agronomic data. If actual seeding practice is 40 kg./ha., an extension program recommending that farmers increase their seed density to 90 kg./ha. would have a good chance of succeeding: the likelihood of exceeding the expected worst profit at the lower density of 40 kg./ha. is 92% and the likelihood of doing better than a farmer using 40 kg./ha. is 69%. These confidence bounds, being calculated for individual farmers and not for the mean profit of groups of farmers, are conservative; the average profit will have tighter confidence bounds. Barring extraordinarily bad climatic conditions, the peasants would quickly be convinced of the value of the proposed seed density.

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References

Anderson, J. R., J. L. Dillon, and B. Hardaker. *Agricultural Decision Analysis.* Ames: Iowa State University Press, 1977.

Camerman, P. *Essais de rendement de haricots nains pour diverses densités de semis.* Butare: Institut des Sciences Agronomiques du Rwanda, 1976.

Dillon, J. L. *The Analysis of Response in Crop and Livestock Production,* 2nd ed. Oxford: Pergamon Press, 1977.

Dillon, J. L., and P. L. Scandizzo. "Risk Attitudes of Subsistence Farmers in Northeast Brazil: A Sampling Approach." *Amer. J. Agr. Econ.* 60(1978):425–35.

Heady, E. O., and J. L. Dillon. *Agricultural Production Functions.* Ames: Iowa State University Press, 1961.

Moscardi, E., and A. de Janvry. "Attitudes toward Risk among Peasants: An Econometric Approach." *Amer. J. Agr. Econ.* 59(1977):710–16.

Sokal, R. R., and F. J. Rohlf. *Biometry, the Principles and Practices of Statistics in Biological Research.* San Francisco: W. H. Freeman & Co., 1969.

Ex Ante Appraisal of New Technology: Sorghum in Northeast Brazil

Joseph B. Goodwin, John H. Sanders, and Antonio Dias de Hollanda

With the renewal of interest in agriculture in developing countries during the sixties, there has been much concern with the policy instruments to stimulate output without penalizing the urban consumer. Many countries have utilized the rationing of subsidized inputs such as credit for this purpose. In the seventies, international donors—such as the World Bank and USAID—began pressing developing countries to aim more of their agricultural development programs at small farmers. One response has been to extend the use of a major instrument variable, credit policy, to small farmers. However, small farmers often use very few cash inputs; hence, the effectiveness of this instrument may be low unless combined with others.

A second instrument to increase small farmer incomes is the development of new agricultural technology. Besides the developmental costs of the new technology, recent literature has implied that risk aversion may impede its adoption (Benito, Brink and McCarl, Sanders and Hollanda, Schulter and Mount, Wiens, Wolgin). Econometric analysis of this risk-aversion characteristic has not yet clearly indicated instrument variables to reduce it (Dillon and Scandizzo; Binswanger; Moscardi and de Janvry).

Farmers also will have difficulty subjectively estimating the distribution of returns from new alternatives. The desired information would be this distribution over all possible states of nature, which is unlikely to be available to the farmer presented with an adoption choice. Policies to improve risk perception, such as farm level experiments of new technology, are another type of instrument variable to influence adoption.

Three categories of instrument variables are considered in this paper: a traditional instrument, credit policy; policies to affect risk through reduction in the income variance; and, finally, increased information to improve perception of the distribution of returns from new technology. Modeling is utilized to analyze the relative importance of these instruments on the decisions of small farmers in the northeast of Brazil.

The Region: Semiarid Northeast of Brazil

A principal production system of semiarid northeastern Brazil includes tree cotton, corn, cowpeas, and cattle (Sanders and Hollanda). The small farmer is more crop oriented whereas the large landowner is primarily concerned with livestock production. Other minor crops include sweet potatoes and rice, which are produced on areas with a more dependable supply of water. The above systems utilize a minimum of purchased inputs with seeds and insecticides for cotton as the major expenditure. Long rotation periods are substituted for fertilization. A major feature of this agricultural system is the large yield variance due to the low level and variability of rainfall.

An anomaly of the present cropping system is the production of corn as the principal cereal. In other areas of the world with a similar climate, the major cereal is millet or sorghum rather than corn (Johnson). These crops have two advantages over corn. First, most varieties have shorter maturity periods, typically 70 to 100 days, while corn requires 120 to 150 days. Hence, sorghum and millet generally require a shorter rainy season to achieve a reasonable yield. The second advantage is that sorghum and millet are better able to withstand moisture stress than corn, due to the deeper and more diffuse rooting systems and better stomata control over evapotranspiration (Stewart et al.).

Recognizing this superior production potential in regions with inadequate and irregular rainfall, the Brazilian government, with help from the Ford Foundation, began a research program in 1972 to study the suitability of sorghum varieties. The varieties studied gave substantially higher yields than corn in adverse rainfall years and also have slightly outyielded corn in normal and good rainfall years (Sanders, Johnson). Thus, the sorghum varieties selected demonstrated yield potential equal or

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The analysis for this article was done while Goodwin was with Purdue University, stationed at the National Corn and Sorghum Center of the Brazilian National Agricultural Research Corporation (EMBRAPA); Sanders was a Ford Foundation visiting professor in the masters' program in agrilcultural economics of the Federal University of Ceará, Fortaleza, Brazil, and Hollanda was a graduate student in this program.

The helpful comments of Bruce McCarl, Robert L. Thompson, Marshall Martin, W. W. McPherson, John K. Lynam, Douglas Pachico, and the reviewers of this *Journal* are gratefully acknowledged. The authors would also like to express their appreciation to SUDENE and the World Bank for providing data from their 1973 farm survey.

superior to the existing corn varieties of the region with less yield variability. Besides experiment station and regional variety trials, the research program included farm trials.

The Model

Because sorghum has consistently outyielded corn under experimental conditions and budgeting analysis indicated its profitability in farm trials (Barbosa et al.), *ex ante* analysis of its inclusion as a production alternative taking into account risk aversion and risk perception was a next logical step. The farm-level linear programming model used was a variation of Hazell's MOTAD model. The basic model here includes minimum consumption requirements for corn and cowpeas and is represented by

$$(1)\quad \text{maximize } \mathbf{C}'\mathbf{X} + \Omega\, \mathbf{E}'\mathbf{Y} - \phi K\mathbf{L}\mathbf{d} - (\phi\psi)K\mathbf{R}\delta,$$
$$\text{subject to } A\mathbf{X} + S\mathbf{Y} \leq \mathbf{B}$$
$$D\mathbf{X} + I\mathbf{d} \geq \mathbf{0}$$
$$Z\mathbf{Y} + I\delta \geq \mathbf{0}, \text{ and}$$
$$\mathbf{X}, \mathbf{Y}, \mathbf{d} \text{ and } \delta \geq \mathbf{0},$$

where **B** represents resource availabilities to the farmer and **X**, A, and **C** represent activity levels, resource uses, and expected gross incomes for the nonsorghum activities. **Y**, S, and **E** represent the activity levels, resource use, and expected gross incomes for the sorghum activity. The elements in the deviation matrix D represent the difference between observed and expected gross income for the nonsorghum activities for the years covered in the analysis, while the elements in the deviation matrix Z are the differences in observed and expected gross incomes for the sorghum activities for the years included in the model. The vectors **d** and δ represent the yearly total negative deviation summed over the nonsorghum and sorghum activities, respectively, while **L** and **R** are vectors of ones which sum the elements of **d** and δ over the k years in the model. They provide the estimates of the summed negative deviation, which are transformed, respectively, into estimates of the standard deviation of income for the nonsorghum and sorghum activities by multiplication by the constant K, converting the total negative deviation to an estimate of the standard deviation (Brink and McCarl, Simmons and Pomareda).

In the above model formulation, risk affects the farmer's decision to adopt new technology in two ways: risk aversion and risk perception. The risk-aversion coefficient, ϕ, is the standard utility function weighting of income and a proxy for income variance. The farmer's perception of new technology from limited observations is an innovation in this model. The behavioral assumption about perception is that a farmer will observe a new technology in the same or similar agro-climatic conditions. Then he will discount the yield data according to his knowledge of the probabilities for the states of nature observed and fill in the missing observations with his subjective expectations about prices and yields. As the farmer's utility function trade-off between income and variance has proven to be useful in explaining present cropping patterns, the farmer's subjective estimate of the potential returns to a new technology is expected to be an important factor in the adoption decision. The coefficients, Ω and ψ, adjust for the farmer's perception of expected returns and the proxy for income variance of the new technology activities.

The Data

The above model was developed for a representative small farm of the Brazilian semiarid Northeast, based upon the 1973 SUDENE/World Bank farm level survey and subsequent field interviewing in the Serido of Rio Grande do Norte. Activities in the linear programming model consists of both pure stand and intercropped combinations. New sorghum activities also were introduced into the intercropped system, with sorghum substituting for the corn or the corn and cowpeas. Price of sorghum was set equal to 90% of corn, the relative price at the time. For those years in which farm level data for sorghum were lacking, the same perceptual relationship between sorghum and corn yields, as observed in experiment station trials, was utilized to synthesize the farm yields. For further description of the region and activity choices, see Sanders and Hollanda.

Model Validation and New Technology

In simulating the choice of cropping activities, there have been two predominant methods for estimating the risk-aversion coefficient: direct elicitation, as used by Dillon and Scandizzo and Binswanger; observed factor demand and output supply behavior as in Moscardi and de Janvry and in Brink and McCarl. In the latter, indirect method utilized here, the risk-aversion coefficient is selected, which minimizes the difference between predicted and actual plans. This may overestimate risk aversion by attributing the entire difference between risk neutral and actual output levels to risk aversion. Other explanations, such as differences in resource availability, imperfect information on future prices, and differences in subjective probability assessments, could explain the differences between actual and simulated cropping plans. Even if overestimated, the risk-aversion measure is still useful to evaluate the total impact of uncertainty about various parameters and aversion to risk upon farm plans and income levels.

The model estimated a high risk-aversion level of 3.28 for the small farmers utilizing the present crop mix. In other runs not reported, cropping decisions

were insensitive to changes in credit conditions and to the availability of more land at these high risk-aversion levels. An extensive land use is encouraged by the livestock operation and the substitution of long rotation periods for fertilization. As shifts occur to more intensive land use, the livestock operation must become intensive or decrease.

At the present level of risk aversion, the gains from new technology are small, as indicated by the distance AC in figure 1—which also shows that the income gains from reducing risk aversion are substantial for either present or new technology. Reducing the income variance of new technologies through yield insurance or price supports would have the same effect as reducing the risk-aversion coefficient. With the correct perception of the returns to the new sorghum activities, a sorghum association enters at even the highest level of risk aversion. At lower levels of risk aversion, a more intensive sorghum technology with fertilization was introduced further augmenting the income level (table 1).

For simplification, the perception of the income variance of the new technology activities was assumed exaggerated. That is, farmers were assumed to overestimate the downside risk and the extension agent to overstate the potential profitability ($\Omega = 1$ and $\psi = 1.5$). Even with the variance of income from sorghum overestimated and at the highest risk-aversion level, a sorghum activity still came into the solution. Input use and area in sorghum were less than with the "correct" perception of income variance. Nevertheless, the new technology was still introduced on a small area.

At present levels of risk aversion, demonstration plots of the new technology at the farm level to improve the perception of the distribution of returns would be expected to be effective in hastening farmer awareness of the advantages of sorghum, thus speeding the adoption process; whereas credit policy of variation in the interest rates had no effect. At lower risk-aversion rates, the adoption of new sorghum technology with fertilization was hastened with subsidized credit (compare cases 2 and 3 of table 1).[1]

The largest income gains would come from a policy mix that would reduce both risk aversion and risk misperception associated with the new technology. With risk misperception, the reduction of risk aversion from 3.28 to 2 results in a 43% in-

[1] For informal credit, a 40% interest rate was considered to be a conservative estimate based upon unpublished data from farm surveys in Canindé, Ceará, 1973–75, Department of Agricultural Economics, Federal University of Ceará, Fortaleza, Brazil. There exists a government credit program in which farmers are eligible to receive loans at 8% up to a ceiling of fifteen minimum salaries.

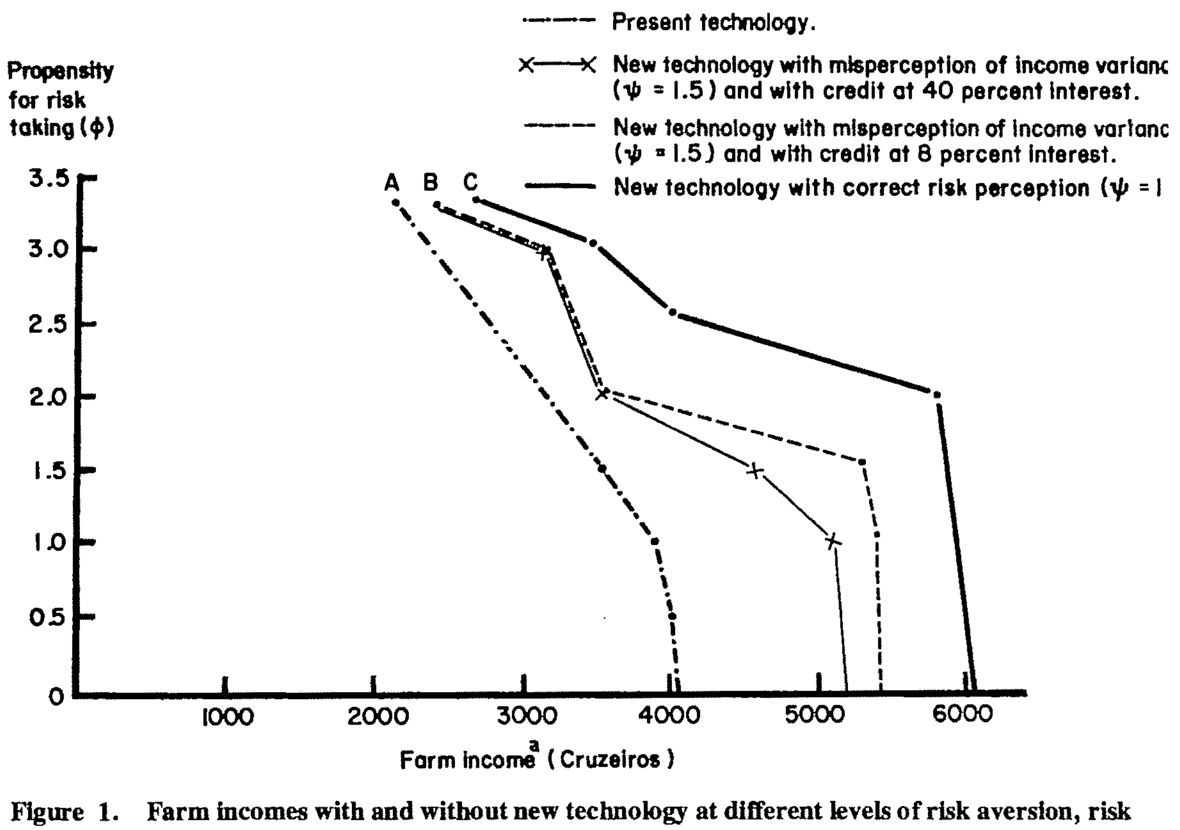

Figure 1. Farm incomes with and without new technology at different levels of risk aversion, risk perception, and varying credit conditions

[a] This is a standard gross margin of programming analysis.

Table 1. New Technology and Income at Different Risk Aversion, Risk Perception, and Credit Conditions

Case 1. New Technology with Risk Correctly Perceived (ψ = 1 and credit at 40%)						
Risk aversion	$\phi = 0$	$\phi = 2.0$	$\phi = 2.5$	$\phi = 3.0$	$\phi = 3.28$	
Income[a]	$\pi = 6{,}067$	$\pi = 5{,}781$	$\pi = 4{,}010$	$\pi = 3{,}474$	$\pi = 2{,}691$	
	Cotton-Sorghum Fertilized 5.6 ha.	Cotton-Sorghum Fertilized 5.2 ha.	Cotton-Sorghum 60% fertilized 40% unfertilized 5.1 ha. Cotton-Sorghum-Cowpeas Unfertilized 0.4 ha.	Cotton-Sorghum Unfertilized 3.9 ha. Cotton-Sorghum-Cowpeas Unfertilized 1.6 ha.	Cotton-Sorghum Unfertilized 3.9 ha. Cotton-Sorghum-Cowpeas Unfertilized 1.6 ha.	
Case 2. With Risk Misperception (ψ = 1.5 and credit at 40%)						
Risk aversion	$\phi = 0$	$\phi = 1.0$	$\phi = 1.5$	$\phi = 2.0$	$\phi = 3.0$	$\phi = 3.28$
Income[a]	$\pi = 5{,}168$	$\pi = 5{,}137$	$\pi = 4{,}610$	$\pi = 3{,}551$	$\pi = 3{,}250$	$\pi = 2{,}476$
	Cotton-Sorghum Fertilized 5.6 ha.	Cotton-Sorghum Fertilized 5.0 ha.	Cotton-Sorghum Fertilized 3.4 ha.	No sorghum activity	Cotton-Sorghum-Cowpeas Unfertilized 0.7 ha.	Cotton-Sorghum-Cowpeas Unfertilized 0.8 ha.
Case 3. With Risk Misperception and Subsidized Credit (ψ = 1.5 and credit at 8%)						
Risk aversion	$\phi = 0$		$\phi = 1.5$	$\phi = 2.0$	$\phi = 3.0$	$\phi = 3.28$
Income[a]	$\pi = 5{,}405$		$\pi = 5{,}323$	$\pi = 3{,}551$	$\pi = 3{,}250$	$\pi = 2{,}476$
	Cotton-Sorghum Fertilized 5.6 ha.		Cotton-Sorghum Fertilized 5.6 ha.	No sorghum activity	Cotton-Sorghum-Cowpeas Unfertilized 0.7 ha.	Cotton-Sorghum-Cowpeas Unfertilized 0.8 ha.

Note: Nonsorghum activities were not included in the table.
[a] Gross margin in cruzeiros; ψ is perception of the variance of income from sorghum; Ω = 1, or there is correct perception of the expected returns from sorghum.

crease in mean income (Case 2 in table 1). However, an equivalent reduction in risk aversion accompanied by the elimination of risk misperception would give a 133% income increase. Similarly, income gains from elimination of risk misperception of only 9% and 63% at risk-aversion levels of 3.28 and 2 are obtained.

Conclusions

High levels of risk aversion have led many to be pessimistic about the potential for raising the income of small farmers with new agricultural technology, especially in resource poor regions such as the Brazilian Northeast. In developing countries, research and extension efforts generally have concentrated on the agricultural regions with the best resources and often the largest farmers. Outmigration to urban areas or decentralization of industrialization have been recommended to raise the income of small farmers in these poorer agricultural resource areas. However, income increases are possible in agriculture with new technology and associated policy measures. The model indicates that new technology, appropriate for the farmers and the region, should be adopted by farmers highly averse to risk even with an overestimation of the variance of the returns. For nonadopters, improved estimates of the distribution of returns will occur over time as their neighbors adopt and they obtain more information on the new technology.[2] Crop research programs may need to consider several alternative technologies, as the model results for the sorghum technology adopted were highly influenced by the farmer's risk-aversion coefficient.

Ex ante technology evaluation by simulating farm conditions appears to be useful for ascertaining the feasibility of new technology and the farm level constraints to its introduction. A series of complementary policy measures to the introduction of the new technology were identified; however, these are still model results and clearly depend upon verification of both the synthesized data for sorghum and the assumptions about farmers' perceptions of the returns to the sorghum activities (Ω and ψ).

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References

Anderson, J. R., J. L.Dillon, and J. B. Hardaker. *Agricultural Decision Analysis.* Ames: Iowa State University Press, 1977.

Barbosa, A. R., J. H. Sanders, and H. J. Abdon de Lyra. *Opções Technológicas para a Região Semi-Arida do Rio Grande do Norte* Natal: Comissão Estadual de Planejamento Agricola do Rio Grande do Norte, 1976.

Benito, C.A. "Peasants' Response to Modernization Projects in Minifundia Economics." *Amer. J. Agr. Econ.* 58(1976):143–51.

Binswanger, H. P. "Attitudes toward Risk: Experimental Measurement in Rural India." *Amer. J. Agr. Econ.* 62(1980):395–407.

Brink, L., and B. McCarl. "The Tradeoff between Expected Returns and Risk among Cornbelt Farmers."*Amer. J. Agr. Econ.* 60(1978):259–63.

Dillon, J. L., and J. R. Anderson. "Allocative Efficiency, Traditional Agriculture, and Risk." *Amer. J. Agr. Econ.* 53(1971):26–32.

Dillon, J. L., and P. L. Scandizzo. "Risk Attitudes of Subsistence Farmers in Northeast Brazil: A Sampling Approach." *Amer. J. Agr. Econ.* 60(1978):425–35.

Hazell, P. B. R. "A Linear Alternative to Quadratic and Semivariance Programming for Farm Planning under Uncertainty." *Amer. J. Agr. Econ.* 53(1970):53–62.

Johnson, D. "Sorgo Granífero no Nordeste do Brasil." *Revista Economica do Nordeste* 9(1978):483–500.

Moscardi, E., and A. de Janvry. "Attitudes toward Risk among Peasants: An Econometric Approach." *Amer. J. Agr. Econ.* 59(1977):710–16.

Sanders, J. H. "New Agricultural Technology in the Brazilian Sertão." Paper presented at ICRISAT Conference, Hyderabad, India, Feb. 1979.

Sanders, J. H., and A. D. de Hollanda. "Technology Design for Semiarid Northeast Brazil." *Economics and the Design of Small Farmer Technology*, ed. A. Valdés, G. M. Scobie, and J. L. Dillon. Ames: Iowa State University Press, 1979.

Schulter, M. G., and T. D. Mount. "Some Management Objectives of the Peasant Farmers: An Analysis of Risk Aversion in the Choice of Cropping Pattern, Surat District, India." *J. Develop. Stud.* 12 (1976):246–61.

Simmons, R. L., and C. Pomareda. "Equilibrium Quantity and Timing of Mexican Vegetable Exports." *Amer. J. Agr. Econ.* 57(1975):472–79.

Stewart, J. I., R. D. Misia, W. D. Pruitt, and R. M. Hagan. "Irrigating Corn and Sorghum with a Deficient Water Supply." *Transactions Amer. Soc. Agr. Eng.* (1975):270–80.

Wiens, T. B. "Peasant Risk Aversion and Allocative Behavior: A Quadratic Programming Experiment." *Amer. J. Agr. Econ.* 58(1976):629–35.

Wolgin, J. M. "Resource Allocation and Risk: A Case Study of Smallholder Agriculture in Kenya." *Amer. J. Agr. Econ.* 57(1975):622–30.

[2] The adoption process is analyzed for an individual farm and does not consider the market effect of expanded production.

An Evaluation of Goal Hierarchies for Small Farm Operators

Wilmer M. Harper and Clyde Eastman

Considerable attention recently has been focused on the small farm sector in the United States. Regional small farm conferences were sponsored by the U.S. Department of Agriculture (USDA) during 1978 (USDA 1978b); the ESCS held a Small-Farm Workshop (USDA 1978c); and the National Small Farms Conference was sponsored by the National Rural Center (Madden and Tischbein) in February 1979. If agricultural policy is to facilitate the accomplishment of small farmers' objectives, then a central issue must be the determination of small-farm operators' goals and objectives. If these differ substantially from those of large farm units, one policy position hardly could be consistent with meeting the needs of both groups.

Although economic theory of the firm typically assumes the maximization or minimization of a single goal or objective, a body of knowledge concerning the behavioral framework within which the firm functions has been queried and delineated. Simon developed the conceptualization of rational behavior that is compatible with the access to information and computational capacities as a replacement for the global rationality of economic man. With respect to the family-managed farm, Heady further emphasized the fact that the farm is a complete economic unit in which the interdependence between income and consumption casts doubt upon the assumption of profit as the ultimate quantity which the farm family attempts to maximize. Although multiple goals and lexicographic ordering are recognized (Ferguson), analysis tends to focus upon an identifiable, operable goal, such as profit maximization. Research has defined and quantified the hierarchy of goals, attitudes, and decision-making criteria for production units that may be classified as commercial and/or large-scale producers (Harman et al.; Bostwick, Esmay, Rodewald), but attention has not been directed toward the small farm unit.

Low or negative returns to equity and high opportunity costs for both human and equity capital are frequently cited as reasons why farm operators, particularly small farm operators, should, if judged within the criteria of a rational profit maximizer, be expected to cease agricultural production and reallocate their resources. Development of goal hierarchies for the operators of small farm enterprises will serve as a departure point for the evaluation of the position that small farm operators exhibit incongruent economic behavior.

Typical of the general analytic approach taken by most agricultural economists toward small farm organization and operation is that chosen by Metzger and Flanders. On the basis of a linear programming model, they develop strategies for maximizing income within a set of resource constraints. Complementary to this procedure is the position that increasing the managerial skills and capabilities of limited resource farmers is an effective means of integrating them into the process of economic development (McKenzie). Even when directed toward behavioral parameters of small farm operation, studies have focused more on behavior than determinants of behavior. In their study of limited resource farmers, Blackburn, Brinkman, and Driver indicate that one of their objectives was to determine the social, economic, and humanistic expectations of the farmers who plan to stay in agriculture; however, the study addressed behavioral characteristics such as amount of fertilizer used rather than goals and objectives for the family or farm. Behavioral characteristics are important in the evaluation of goal achievement, but they do not constitute goals and objectives. It is conceivable that behavior may preclude the accomplishment of a given goal or objective, particularly if the goal is taken to be profit maximization. For example, a family that indicates that income or profit is the major goal may engage in a traditional production activity even though an alternate activity would yield higher profits.

The analysis reported herein develops a goal hierarchy for a randomly selected sample of small farm operators in New Mexico and is part of a larger study for the determination and analysis of the socioeconomic characteristics of New Mexico's small farm and small ranch operators. Two sets of goals are evaluated: goals for the family unit and goals for the agricultural enterprise. Given that many operators of small farms and ranches in New Mexico or their spouses have off-farm employment, these two goal sets allow an evaluation of the poten-

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tial conflict between family unit goals and agricultural enterprise goals.

Analytic Framework

The method of paired comparisons (Edwards, Bradley) was used to develop the ranking of a goal hierarchy for the small farm units. The assumptions of the paired comparisons model used by this analysis are those of the model formulated by Mosteller (1951a). The model allows the determination of a rank ordering of the goals, and with the selection of one goal as *numeraire*, scale values may be developed for each goal, which places the goals on a relative continuum.

The most probable violations of the model and, therefore, potential criticisms are a contingent lack of normality in the sample and failure of the population to have equal standard deviations. Mosteller indicates, however, that normality is not essential for the application of the method of paired comparisons, being more in the nature of a computational device (1951b).

Goal Selection

The method of paired comparisons requires that the respondent be presented with a list of all possible pairs of goals within the given set and that the respondent select the preferred goal in each pair. The number of pairs for a given set is equal to n ($n - 1$)/2, where n is the number of items in the set.

The sets of goals were required to meet two criteria: that they allow a comparison of the family goals with goals for the agricultural enterprise and that goals for the agricultural enterprise approximate items used in a prior study of goal hierarchies for agricultural enterprise operators (Harman et al.). Some questions from this earlier study of goal hierarchies were modified to facilitate their interpretation by the respondents and their applicability to the area, but comparability with the prior study was retained.

Based upon pretest results, the analysis utilized the following sets of goals:[1]

	Goal Identification Code
Family Goals	
To maximize social status/prestige	G1
To maximize income	G2
To maximize material accumulations (net worth)	G3
To maximize quality of life	G4
To maximize consumption	G5
Agricultural Goals	
To control more acreage (to increase the size of your operation by leasing, renting, or buying more land)	AG1
To have newer and larger equipment and buildings	AG2
To make more profit each year (net above farm costs)	AG3
To avoid being forced out of agriculture	AG4
To avoid years of low profits or high losses	AG5
To increase your net worth as derived from your agricultural operation	AG6
To maintain or improve the family's quality of life that results from its involvement in agriculture	AG7

[1] The goals were designed to measure preferences toward certain socioeconomic goals or concepts: Quality of life—G4, AG7, and AG4; preference for income—G2, AG3, and AG5; preference for net worth—G3 and AG6; preference for consumption—G5 and AG1; and preference for more social status or prestige—G1 and AG2.

Respondents were presented with each pair of goals and asked, for example, "Would you prefer to maximize social status and prestige or to maximize income?" If the respondent indicated an uncertainty concerning the meaning of a given goal or concept, the interviewer offered one example for clarification. Although this may have resulted in some bias in these responses, all interviews were conducted by one individual so that there was consistency in the interpretations given to respondents.

Family goals were stated in terms of "maximizing" rather than "satisficing," to minimize the subjectiveness of the standard against which the respondents would evaluate each pair of goals.

Data

The state was divided into nine regions, classified as homogenous by type of agricultural activity, and a county was then drawn at random from each region. From lists of agricultural producers maintained by each county extension office, a set of farm operators who met the criterion of less than $40,000 gross agricultural sales for the accounting period 1977 were selected at random. These lists contain the names of individuals who have contacted the extension office for information or services or who have participated in extension-sponsored activities of any type. Although not all-inclusive, these lists represented the best available defined frame from which to draw a sample. A screening question eliminated those with gross agricultural sales exceeding $40,000.

Analysis

Significance of goal rankings was determined at the 0.05 significance level by the method reported in

Urquhart and Eastman. The test statistic for the chosen significance level was

$$LSD = 1.96\,[B(t)(t+1)/6]^{1/2},$$

where LSD is the least significance difference between the number of responses, B is the number of respondents, t is the number of items to be ranked, and the hypotheses evaluated were

$$H_0\colon R_i = R_{i+1}$$

$$H_1\colon R_i \neq R_{i+1},$$

where R_i is the rank of the ith item in the set of goals. The null hypothesis is rejected if $(T_i - T_{i+1}) < LSD$, where T_i is the total number of times that a given goal is preferred over any other goal (see tables 1 and 2).

Rank Order of Goals

The results of the survey of operator goals are presented in tables 1 and 2. The numbers in each column indicate the frequency with which a goal was preferred to each other goal, represented by the respective rows. Reading across the tables, the numbers in a given column of that row indicate the frequency with which the goal represented by that row was not preferred to the goal represented by the given column.

The columns in each table have been arranged so that the goals appear in ascending order. T_i for any goal is the sum of the representative column. LSD for tables 1 and 2 are 46.76 and 34.23, respectively. Given the test criteria and LSD statistics, the analysis fails to reject the null hypothesis only in the case of AG1. This results in the following hierarchies of goals:

	Goal Identification Code
Family Goals	
To maximize quality of life	G4
To maximize income	G2
To maximize material accumulations (net worth)	G3
To maximize consumption	G5
To maximize social status/prestige	G1
Agricultural Goals	
To maintain or improve the family's quality of life that results from its involvement in agriculture	AG7
To avoid being forced out of agriculture	AG4
To avoid years of low profits or high losses	AG5
To make more profit each year (net above farm costs)	AG3
To increase your net worth as derived from your agricultural operation	AG6
To control more acreage (to increase the size of your operation by leasing, renting, or buying more land)	AG1
To have newer and larger equipment and buildings	AG2

Within each hierarchy, each goal is significantly more important than the succeeding goal with the exception of AG6. In this case the total times that AG6 was preferred to AG1 was not sufficient to differentiate statistically between AG6 and AG1.

Table 1. Frequency Matrix and Rank of Agricultural Goals for Sixty-One Small Farm Families in New Mexico, 1977

Goal	AG2	AG1	AG6	AG3	AG5	AG4	AG7	Total
AG2	—	42 (68.85)[a]	52 (85.25)	60 (98.36)	60.5[b] (99.18)	59 (96.72)	61 (100.00)	334.5
AG1	19 (31.15)	—	28 (45.90)	58 (95.08)	60 (98.36)	60 (98.36)	60 (98.36)	285
AG6	9 (14.75)	33 (54.10)	—	48 (78.67)	55 (90.16)	57 (93.44)	58 (95.08)	260
AG3	1 (1.64)	3 (4.92)	13 (21.31)	—	50 (81.97)	58 (95.08)	58 (95.08)	183
AG5	0.5[b] (0.82)	1 (1.64)	6 (9.84)	11 (18.03)	—	54 (88.53)	58 (95.08)	130.5
AG4	2 (3.28)	1 (1.64)	4 (6.56)	3 (4.92)	7 (11.48)	—	53 (86.88)	70
AG7	0 (0.00)	1 (1.64)	3 (4.92)	3 (4.92)	3 (4.92)	8 (13.12)	—	18
Total	31.5	81	106	183	235.5	296	348	1,281
Rank	7	6[c]	5	4	3	2	1	n.a.

[a] Numbers in parentheses indicate the percentage of the total respondents represented by the frequency.
[b] If the respondent could not choose between the two goals, the response was divided equally between the two goals.
[c] Ranking not significant at the 0.05 level.

Table 2. Frequency Matrix and Rank Ordering of Family Goals for Sixty-One Small Farm Families in New Mexico, 1977

Goal	G1	G5	G3	G2	G4	Total
G1	—	57 (93.44)[a]	61 (100.00)	61 (100.00)	60 (98.36)	239
G5	4 (6.56)	—	48.5[b] (79.51)	54 (88.52)	60 (98.36)	166.5
G3	0 (0.00)	12.5[b] (20.49)	—	53 (86.88)	59 (96.72)	124.5
G2	0 (0.00)	7 (11.48)	8 (13.12)	—	48 (78.69)	63
G4	1 (1.64)	1 (1.64)	2 (3.28)	13 (21.31)	—	17
Total	5	77.5	119.5	181	227	610
Rank	5	4	3	2	1	n.a.

[a] Numbers in parentheses indicate the percentage of the total respondents represented by the frequency.
[b] If respondent could not choose between the two goals, the response was divided equally between the two goals.

These two goals would, therefore, be considered of equal significance in the hierarchy.

Family versus Agricultural Goals

Family goals in this study focus upon the respondents' appraisal of goals which are homocentric to the family unit. The generalized goals utilized in the survey were intended to define the socioeconomic orientation of the family unit rather than to focus upon specific activities.

Agricultural goals focus upon specific objectives for the agricultural activities of the family unit. These allow identification of the socioeconomic goals for the family's present and continued involvement in agriculture.

An evaluation of the consistency between goals for the family unit and goals for the agricultural enterprise is relevant to a consideration of small farm operator goals for three reasons: the large amount of nonfarm income earned by these family units, the opportunity cost of farm labor, and the returns to equity. Only 4.9% of the small farm units surveyed relied totally upon the income generated by their farm operation and more than 50% of the units had more nonfarm than farm income. Opportunity cost of farm labor enters any comprehensive consideration of farm policy (Tweeten). In 1976, the U.S. farm population received 59% of its personal income from nonfarm sources (USDA 1978a, p. 464), and the off-farm income for farm families with gross agricultural sales of $39,999 or less ranged from $5,762 to $15,630 (USDA 1977, p. 94). The percentage of returns to equity for the classes of farms considered in this study range from −6.5 to 4.4 for the United States and from −3.9 to 4.2 for the Mountain States (Hottel and Reinsel, pp. 25, 60). The magnitude of nonfarm income to farm income and the negative or low returns to farm equity suggest the possiblity that agricultural goals may be in conflict with family goals.

To evaluate consistency between the ranking of the two sets of goals and, therefore, any conflict between family and agricultural goals, the analysis considered the two sets in terms of their socioeconomic content. To accomplish this comparison, agricultural goals were compared with family goals to see if goals with similar socioeconomic content had a similar relative rank within their respective hierarchy. Because there are more goals in the set of agricultural goals, relative rank becomes the relevant judgmental criterion for consistency. When the two hierarchies are grouped such that the socioeconomic content corresponds across groups (see fn. 1), the following grouping results where the numbers in parentheses are the respective ranks (see tables 1 and 2) of the goals within the given hierarchy:

Family Goals	Agricultural Goals
G4(1)—quality of life	AG7(1)—quality of life AG4(2)—remain in agriculture
G2(2)—income	AG5(3)—avoid low profit/high loss AG3(4)—profit
G3(3)—net worth	AG6(5)—net worth
G5(4)—consumption	AG2(7)—new/larger equipment
G1(5)—social status	AG1(6)—more acreage

Quality of life ranks highest in both sets of goals. AG7 deals directly with quality of life, and, if one considers quality of life derived from agricultural activities to be important, then AG4 must also contribute to agriculturally derived quality of life. AG5 and AG3 are both directly related to the income to be derived from agricultural activities. In the grouping shown above, AG7 and AG4, and AG5 and AG3 were grouped together so that relative rank of the socioeconomic content within the hierarchies may be compared more easily. After quality of life, income and net worth rank, respectively, are highest in both hierarchies. The relative ranking of goal

content across the hierarchies fails to correspond at the lower end of the two sets.

Although the symmetry of the socioeconomic content of the goals in the two sets is not complete, it is sufficient to support the tentative conclusion that for this set of small farm operators, family and agricultural goals are compatible and appear to be nearly congruent.

Agricultural Goals

Having established a correspondence between the family goals and the agricultural goals for the small farm unit in New Mexico, the analysis evaluated the symmetry between the hierarchy of agricultural goals established by this analysis and the hierarchy of goals for a set of farm operators in a study conducted in Oklahoma and Texas (Harman et al.). The study does not assume that the NM and OK/TX samples are drawn from populations that are similar in all respects and are, therefore, subsets of the same population. It assumes only that with respect to income they come from the same subset of the U.S. farm population. The OK/TX study considered a much wider range of income than is included in the NM sample, but it determined goal hierarchies for various subsets of the total study population. The OK/TX goal hierarchy used for comparison in this study for the income range which, when converted to 1977 dollars, corresponds to the income range of the NM sample.

The rankings for each goal as established by the New Mexico study (NM) and the Oklahoma-Texas (OK/TX) study, respectively, are

	AG7	AG4	AG5	AG3	AG6	AG1	AG2
NM:	1	2	3	4	5	6	7
OK/TX:	5	6	2	1	3	7	n/a

The OK/TX study did not include a goal similar to AG2 of the NM study, and since New Mexico small farm operators traditionally prefer not to borrow capital, a "reduce borrowing needs" question of the OK/TX study was not included in the NM survey.

Although the goals presented to each study group were not precisely the same, the similarity is sufficient for some tentative generalizations. First and most obvious is the lack of correspondence between the rankings of the two groups. Second and equally important is the reversal of emphasis in the rankings with respect to profit and quality of life. This reversal may be due to a regional/cultural difference or to a general change since 1972 in the socioeconomic environment of the country, but as a source of variation, either of these has significant implications.

Conclusions

The results of this analysis demonstrate the feasibility of developing a statistically significant hierarchy of goals for small-farm production units, and the hierarchies developed allow some tentative conclusions to be drawn about the decision-making criteria of the small farm unit. The attitude toward profit maximization from agricultural activities suggests that they may, in part, view involvement in agriculture as a consumption good. The emphasis upon family quality of life derived from agricultural activity, above profits, indicates that the family is the relevant unit of analysis rather than the farm enterprise. This socioeconomic orientation suggests that operators of production units similar to those in the data set of this analysis may view their agricultural activities as meeting a personal, nonmonetary need first and an income need second. Although the sample used in this analysis is not large enough to extrapolate to all small farm units, the results suggest the existence of a large group of farm operators who may be hypothesized to be less responsive to the standard commodity-oriented agricultural policy. It would appear, therefore, that a household production function approach (Becker, Gronau) or an allocation of time and goods among activities approach (Pollack and Wachter) would yield more insight into the economic activity of the small farm unit than would a profit maximization approach.

Finally, the lack of correspondence between the hierarchy rankings of the New Mexico and the Oklahoma/Texas groups demonstrates the need for additional study. Any policy determination must have at its center an expectation of the behavior which the affected individual or group of individuals will exhibit.

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References

Blackburn, Donald J., George L. Brinkman, and Herbert C. Driver. "Farm Business, Behavioral and Participation Characteristics of Limited Resource Farmers." Ontario Agricultural College, University of Guelph, Apr. 1978.

Becker, G. S. "A Theory of the Allocation of Time." *Econ. J.* 75(1965):493–517.

Bostwick, Don, James Esmay, and Gordon Rodewald. "Attitudinal Research Relating to Farmers' Use of Short-Term Credit." Washington, D.C.: USDA, ERS-25, 1961.

Bradley, Ralph A. "Science, Statistics, and Paired Comparisons." *Biometrics* 32(1976):213–52.

Edwards, Allen L. *Techniques of Attitudes Scale Construction*. New York: Appleton-Century-Crofts, 1957.

Ferguson, C. E. "The Theory of Multidimensional Utility Analysis in Relation to Multiple-Goal Business Behavior: A Synthesis." *S. Econ. J.* 32(1965):169–75.

Gronau, Reubin. "Leisure, Home Production, and Work—The Theory of the Allocation of Time Revisited." *J. Polit. Econ.* 85(1977):1099–1123.

Harman, Wyatte L., Roy E. Hatch, Vernon R. Eidman,

and P. L. Claypool. "An Evaluation of Factors Affecting the Hierarchy of Multiple Goals." Oklahoma Agr. Exp. Sta. Tech. Bull. T-134, June 1972.

Heady, E. O. *Economics of Agricultural Production and Resource Use*. Englewood Cliffs, N.J.: Prentice-Hall, 1970.

Hottel, Bruce, and Robert Reinsel. "Returns to Equity Capital by Economic Class of Farm." Washington, D.C.: USDA ERS Agr. Econ. Rep. No. 347, 1976.

McKenzie, K. J. "Improving Managerial Capabilities of Limited Resource Farmers." *Amer. J. Agr. Econ.* 60(1978):830–33.

Madden, J. Patrick, and Heather Tischbein. "Toward an Agenda for Small Farms Research." *Amer. J. Agr. Econ.* 61(1979):940–46.

Metzger, Homer B., and Nicholas E. Flanders. "Improving the Incomes of Small Farm Families in Coastal Maine." Life Sciences and Agr. Exp. Sta. Bull. 742, University of Maine, 1977.

Mosteller, F. "Remarks on the Method of Paired Comparisons: I. The Least Squares Solution Assuming Equal Standard Deviations and Equal Correlations." *Psychometrika* 16(1951a):3–9.

———. "Remarks on the Method of Paired Comparisons: II. A Test of Significance for Paired Comparisons When Equal Standard Deviations and Equal Correlations are Assumed." *Psychometrika* 16(1951b):203–6.

Pollack, Robert A., and Michael L. Wachter. "The Relevance of the Household Production Function and Its Implication for the Allocation of Time." *J. Polit. Econ.* 83(1975):255–77.

Simon, H. A. *Models of Man*. New York: John Wiley & Sons, 1957.

Tweeten, Luther G. *Foundations of Farm Policy*. Lincoln: University of Nebraska Press, 1970.

U.S. Department of Agriculture. *Agricultural Statistics, 1978*. Washington, D.C., 1978a.

———. "Proceedings of Workshop on: Agricultural and Rural Data." Series B, Washington, D.C., 1977.

———. "Regional Report Albuquerque, New Mexico." *Southwest Small Farms Conference*. Washington, D.C., Nov. 1978b.

———. "Small-Farm Issues: Proceedings of the ESCS Small-Farm Workshop, May 1978." Washington, D.C.: ESCS-60, 1978c.

Urquhart, N. Scott, and Clyde Eastman. "Ranking Energy Policy Alternatives in a Partially Informed Population," pp. 53–65. 1978 Department of Energy Statistical Symposium, Albuquerque, New Mexico, Nov. 1978, Oak Ridge National Laboratory, Oak Ridge, Tenn.

The Effect of Mining on Agricultural Hired Labor in the Northern Great Plains

Richard M. Adams and Dale J. Menkhaus

The supply and demand of labor to agriculture is a topic which has generated little research interest in recent years. Since the comprehensive work by Schuh and associates on the structure of national and regional agricultural labor markets, there have been few studies directly related to such concerns. Recent events suggest that the agricultural labor market may again be a relevant research issue.

On a regional level, the Northern Great Plains (Montana, North Dakota, and Wyoming for the purpose of this study) are experiencing a rapid and unprecedented increase in energy exploration and extraction. While coal production leads the growth of this sector, petroleum, natural gas, and uranium also are being affected by national and international adjustments in the energy market. Physical and economic aspects of energy resources and potential development patterns within the region are well documented (Tyner, Kalter, Wold; Dalsted and Leistritz; LeBlanc, Dalter, Boisvert; Libbin and Boehlje).

The effects of rapid economic development within a predominantly rural setting, such as the Northern Great Plains, involve adjustments within the agricultural labor market. Similar adjustments in the structure of rural labor markets also may be occurring in other regions. For example, the decentralization of manufacturing in the South and the general rural "turnaround" observed by Beale for the nation as a whole indicate potential structural changes within the market for agricultural hired labor.

The purpose of this paper is to investigate the nature of the market for hired agricultural labor in the Northern Great Plains, with particular reference to adjustments attendant to energy development. Specific objectives include: (*a*) specification of a regional labor market model defining the supply and demand for hired agricultural labor; (*b*) assessment of the importance of wages in agriculture and mining in explaining the supply of labor to agriculture, with emphasis on the plausibility of mining growth as an incentive for the transfer of labor out of agriculture; and (*c*) comparison of these results with earlier supply and demand studies for agricultural labor.

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The Problem Setting

Estimates of labor supply elasticities generally are dated, with few available at the regional level. Existing studies thus would not necessarily reflect the current structure of the labor market for the Northern Great Plains. The rural nature of the area, when coupled with the imposition of the growth of mining, adds support to such research, particularly in light of the concerns of agricultural producers for present and future supplies of agricultural labor.

An examination of agricultural and mining employment within the three-state region indicates dramatic changes in employment patterns. For example, between 1970 and 1978 mining employment increased from 20,000 workers to over 42,000, or 110% (U.S. Department of Labor 1979). During this same period, agricultural employment decreased from 26,000 to approximately 23,000 hired workers (USDA *Agricultural Statistics*). Wage rates in each industry increased (in nominal terms), but the absolute difference in wage rates between industries grew substantially, from \$2.40 per hour in 1971 to \$6.19 per hour in 1978. Such a growing differential could constitute a transfer incentive between the two sectors in a regional economy. Further, the rapid growth of mining and other energy subsectors, with high multiplier effects, is creating employment and income growth in the service sectors.

This descriptive evidence lends plausibility to the assertion that the mining industry is accelerating the transfer of labor from agriculture. The Powder River Basin of Wyoming, the principal coal production area in the Northern Great Plains, is typical of the economic base in many of the rural areas experiencing energy expansion, i.e., livestock oriented with no industrial base other than mining. This simple economic structure and the isolation of energy extraction sites from more populous areas of the region suggest that mining employment (and rising wages) may indeed represent an opportunity cost of agricultural employment.

The Model

A simultaneous equation model of the regional demand and supply of hired farm labor was specified to determine the impact of growth in the mining sector on the agricultural hired labor market. The

model follows that developed by Schuh; Tyrchniewicz and Schuh; and Hammonds, Yadav, and Vathama, with minor deviations for the mining sector. The growth of the mining sector is assumed to generate substantial economic activity within the region. The resultant economic growth, particularly as manifested in rising wages, may affect the agricultural labor market, even in the absence of direct substitution between mining and agricultural employment. Specifically, the quantity of hired labor demanded is assumed to be a function of the real agricultural hired labor wage, index of prices received by farmers deflated by the index of prices paid by farmers, and an index of productivity (technology). The quantity of hired labor available (supplied) to agriculture is hypothesized to be a function of the real agricultural hired labor wage, the regional civilian labor force, the real mining wage, and a trend variable.[1] Consistent with the Schuh formulation, each equation is specified in the Nerlove framework to facilitate estimation of both long-run and short-run elasticities.

The Statistical Model

The statistical model is as follows:

$$(1)\quad Y_{1t} = \beta_0 + \beta_1 Y_{2t} + \beta_2 X_{1t} + \beta_3 X_{2t} + \beta_4 Y_{1t-1} + \mu_{1t}$$

$$(2)\quad Y_{1t} = \alpha_0 + \alpha_1 Y_{2t} + \alpha_2 X_{3t} + \alpha_3 X_{4t} + \alpha_4 X_{5t} + \alpha_5 Y_{1t-1} + \mu_{2t},$$

where Y_{1t} (endogenous) is agricultural hired labor for Montana, North Dakota, and Wyoming in year t in thousands (USDA *Agricultural Statistics*); Y_{2t} (endogenous) is the average of Montana, North Dakota, and Wyoming hourly agricultural wage in year t deflated by the Consumer Price Index (USDA *Agricultural Statistics*); X_{1t} is the ratio of the index of prices received over the index of prices paid by U.S. farmers in year t (USDA *Agricultural Statistics*); X_{2t} is the farm productivity index of output per unit of input for the Northern Great Plains in year t (USDA 1977); X_{3t} is the average of Montana, North Dakota, and Wyoming hourly mining wage in year t deflated by the Consumer Price Index (U.S. Department of Labor 1977); X_{4t} is the first difference of the civilian labor force in Montana, North Dakota, and Wyoming in ten thousands in year t (U.S. Department of Commerce 1979); X_{5t} is a time trend variable; and μ_{1t} and μ_{2t} are random disturbances. The α's and β's are structural parameters; β_4 is $1 - \gamma_1$, where γ_1 is the coefficient of adjustment for demand and α_4 is $1 - \gamma_2$, where γ_2 is the coefficient of adjustment for supply.

[1] This variable represents a deviation from the model developed by Schuh (1962, 1966). Schuh used "corrected" nonfarm income to represent alternative employment opportunities. Since the main emphasis of this study is on the impacts of the mining sector on agricultural hired labor, alternative income opportunities are represented by the mining wage.

Data

Several assumptions pertaining to the data require discussion before evaluating the results. First, the selection of the study region is motivated by the significant position of this region in national coal production. The Fort Union Coal Formation, located primarily in Montana, North Dakota, and Wyoming, is experiencing rapid exploitation.

The data for agriculture and mining wages are represented by those observed in the above states. Consistent with the Schuh, and Hammonds, Yadav, and Vathama formulations, wage data are deflated. Agricultural employment represents the hired farm labor force in Montana, North Dakota, and Wyoming. The civilian labor force includes nonagricultural employees in the three-state region. Finally, national data for prices received and paid by farmers are used to represent the income to farming and ranching in the region. All data are for the period 1964–78.

Statistical Considerations

There are problems associated with the application of the above model, especially with time-series data. The issue of serial correlation and the test for its presence are well-documented (Griliches 1961, 1967; Durbin). One means of dealing with serial correlation is to assume its existence and adjust for its presence using appropriate estimation procedures, such as the Cochrane-Orcutt iterative technique. The Cochrane-Orcutt technique, incorporating suggestions by Fair concerning the formation of instrumental variables, was employed to estimate the economic model.

Another common problem in Nerlovian-type models is the tendency of the lagged dependent variable to pick up the effect of omitted variables, leading to potential specification bias. This problem may be treated in part by inclusion of a trend variable (Schuh, p. 313; Hammonds, Yadav, Vathama, p. 245). Including trend, however, aggravates the already severe collinearity problems associated with models of this type. In the present study, high intercorrelation (.98) exists between the trend variable and the real agricultural wage, which appears in both the supply and demand equations. As a result of this high interdependence and supported by results of previous studies (Schuh and Leeds; Hammonds, Yadav, Vathama), the trend variable was not included in the demand equation. Thus, caution should be exercised in interpreting the direct price elasticities obtained from the estimated demand relationship due to possible specification bias.

From an economic standpoint, the omission of the trend variable from the demand equation may not be particularly serious, because the production index variable included in the demand equation should be measuring the influence of technology.

However, in the supply equation the inclusion of a trend variable is deemed important in terms of explaining the secular movement in the flow of labor out of agriculture due to changes in tastes for employment in specific industries, aspects of industrialization, and the level of education (Tyrchniewicz and Schuh, pp. 542, 551). Even though collinearity exists between trend and the real agricultural wage, there appears to be theoretical justification to retain the trend variable in the supply equation.

High collinearity also exists between the civilian labor force and real agricultural and mining wage, .97 and .95, respectively. Following Kmenta (p. 390), the civilian labor force data were transformed to first differences to reduce the collinearity.

Results and Implications

A priori expectations concerning the signs of the variables included in the above model are suggested by theory. Within the demand structure (derived), one may hypothesize that the quantity demanded is inversely related to the price (wage) of labor and the productivity index and directly related to the price indices ratio and the lagged value of the dependent variable. On the supply side, quantity supplied is expected to be directly related to the agricultural wage and the civilian labor force and inversely related to the mining wage and trend. The simultaneously estimated regression coefficients for the above economic model are presented in table 1. The results appear to be generally consistent with theoretical expectations.

As is evident from table 1, the statistical results for the demand equation are more robust than for the supply relationship. Specifically, the agricultural wage, the price indices ratio, and the lagged dependent variable are significant at the 5% level and display signs consistent with expectations. Also, the R^2 associated with the demand equation is greater than that observed for the supply relationship.[2] Only the productivity index displays an inconsistent sign. On the supply side, the results are less robust but do display general consistency of signs. Only the change in the civilian labor force, which is insignificant at the 10% level, displays an incorrect sign. Both the agricultural and the mining wage are significant at the 10% level, with the time trend being significant at the 5% level. The F-statistic in both equations is significant at the 5% level.

For economic implications, the significance of several variables bears closer examination. Within the demand equation, the lagged dependent variable (and resultant coefficient of adjustment) is significant, which indicates that substantial adjustments are occurring within the labor market, and

[2] The R^2 in both equations may be artificially inflated due to the presence of the lagged dependent variable.

Table 1. Simultaneous Equation Regression Coefficients for the Northern Great Plains, 1964–78

Equation	Constant	Agricultural Wage	Prices Received ÷ Prices Paid	Productivity Index	Y_{1t-1}	Mining Wage	Change in Civilian Labor Force	Time Trend	Summary Statistics[a] R^2	F	Rho
Demand	8.52 (1.01)	−13.84**[b] (−4.73)	0.25** (4.65)	.08 (1.69)	0.26** (2.73)	—	—	—	0.89	18.05**	−0.49
Supply	66.21 (1.35)	56.04* (1.64)	—	—	0.05 (0.28)	−3.26* (−1.43)	−1.32 (−0.45)	−1.58** (−2.32)	0.72	4.24**	0.19

[a] The t, R^2 and F values are not strictly valid for the second stage of TSLS, since they are based on estimates instead of actual values of endogenous variables. In addition, the t-statistics are biased upward because of the use of the Cochrane-Orcutt iterative technique (Cooper). Since the Cochrane- Orcutt procedure was used to adjust for assumed serial correlation, the value of the Rho is reported rather than the Durbin-Watson statistic.

[b] Single asterisk indicates significantly different from zero at the 10% level; double asterisk indicates significantly different from zero at the 5% level; figures in parentheses are t-values.

conforms to the distributed lag hypothesis. However, the lagged dependent variable in the supply equation, while having the correct sign, is not significant, an observation consistent with Hammonds, Yadav, and Vathama. Also, the significance of the mining wage within the supply equation provides some support to the hypothesized importance of this variable in the agricultural labor market. The implication of this relationship is that continued change in the mining wage does appear to have an effect on the supply of labor to agriculture in this region. The significance of the trend variable lends support to Tyrchniewicz and Schuh's assertion that this variable may be an important shifter of the supply of labor to agriculture.[3]

Based upon the estimated structural relationships presented in table 1, short- and long-run supply and demand elasticities were calculated (table 2). Specifically, demand elasticities were calculated with respect to the agricultural hired labor wage at mean levels and for 1978 to investigate any shifts in the underlying relationship. For the supply equation, elasticities with respect to agricultural wage as well as the mining wage were derived.

The demand elasticity for 1978 was approximately 30% greater than that calculated at the mean level (−0.76 as compared to −1.06). The long-run elasticities increased over short-run values within periods as well as between mean and 1978 levels; i.e., the long-run elasticities are approximately 40% greater in 1978 than for the mean. The absolute levels observed for these elasticities fall within the range observed in earlier studies. The lower elasticities, as compared with those estimated for Oregon, may be attributed to the livestock orientation of the agricultural sector in the Northern Great Plains, which limits the range of substitution possibilities on the input side. The higher values observed in this study, when compared to those estimated by Schuh and Leeds for the Mountain States, may be attributable to a difference in time periods and the larger regional definition in the Schuh study.

Given the emphasis of this study, the supply elasticities are perhaps of greater empirical importance. The values presented in table 2 for the agricultural wage are elastic both at the mean values and for 1978. Such an increase over time is consistent with both Schuh's and Hammond's observations. (Note that the long-run supply elasticity is calculated from an insignificant coefficient of adjustment.) The elasticity with respect to mining wage, which is inelastic, displays the greatest increase over the time period for any of the elasticities calculated, increasing by more than 50% between mean values and 1978. This increase in the response of supply of agricultural labor to changes in the mining wage adds support to the effect of this variable on the

[3] The trend variable may also be capturing the effects of consistent measurement error in some of the variables (Tyrchniewicz and Schuh, p. 551).

Table 2. Demand and Supply Elasticities for Northern Great Plains and Previous Studies

						Previous Studies					
		Agricultural Wage		Mining Wage		Hammonds et al.[a] Agricultural Wage		Tyrchniewicz & Schuh[b] Agricultural Wage		Schuh & Leeds[c] Agricultural Wage	
Equation	Coefficient of Adjustment	Short	Long	Short	Long	Short	Long	Short	Long	Short	Long
Demand											
at means	0.74	−0.76	−1.03	—	—	−1.64 (−0.85)	−3.25 (−1.05)	—	—	−0.130 (−0.12)	−0.349 (−0.40)
at 1978	0.74	−1.06	−1.43	—	—	—	—	—	—	—	—
Supply											
at means	0.95	3.05	3.21*[d]	−0.42	−0.44*	4.02	5.15	0.248*	0.382*	(0.25)	(0.78)
at 1978	0.95	4.28	4.50*	−0.69	−0.73*	—	—	—	—	—	—

[a] Demand and supply elasticities for Oregon calculated at the means for the data period 1951–70. Demand elasticities in parentheses are for the United States for the data period 1941–69.
[b] Elasticities for the mountain region calculated at the means for the period 1929–57.
[c] Elasticities for the mountain region calculated at the means for the period 1929–57. Elasticities in parentheses are for the United States calculated at the means for the period 1929–57, as reported by Schuh.
[d] Asterisk indicates computed from coefficients not significant at the 10% level.

adjustment process with respect to equilibrium levels of agricultural supply and demand. It should be noted that the elasticity of labor supply with respect to mining wages is perhaps a gross effect, given the high multiplier effect of such a basic industry. Further, the elasticity need not and probably does not imply direct substitution. However, the conclusion that agricultural labor is affected by mining does appear plausible in view of the results of this analysis.

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References

Beale, C. L. *The Revival of Population Growth in Nonmetropolitan America*. Washington, D.C.: U.S. Department of Agriculture, ERS-605. June 1975.

Cochrane, D., and G. H. Orcutt. "Application of Least-Squares Regression to Relationships Containing Auto-Correlated Errors." *J. Amer. Statist. Assoc.* 44(1949):36–61.

Cooper, J. P. "Asymptotic Covariance Matrix of Procedures for Linear Regression in the Presence of First-Order Autoregressive Disturbances." *Econometrica* 40(1972):305–10.

Dalsted, N. L., and F. L. Leistritz. *A Selected Bibliography on Coal Energy Development of Particular Interest to the Western States*. Dep. Agr. Econ. Misc. Rep. No. 16, North Dakota State University, Apr. 1974.

Durbin, J. "Testing for Serial Correlation in Least-Squares Regression When Some of the Regressions Are Lagged Dependent Variables." *Econometrica* 38(1970):410–21.

Fair, R. C. "The Estimation of Simultaneous Equation Models with Lagged Endogenous Variables and First-Order Serially Correlated Errors." *Econometrica* 38(1970):507–16.

Griliches, Z. "A Note of Serial Correlation Bias in Estimates of Distributed Lags." *Econometric* 21(1961):65–73.

———. "Distributed Lags: A Survey." *Econometric* 35(1967):16–49.

Hammonds, T. M., R. Yadav, and C. Vathama. "Th Elasticity of Demand for Hired Farm Labor." *Amer J. Agr. Econ.* 55(1973):242–45.

Kmenta, J. *Elements of Econometrics*. New York: Mac millan Co., 1971.

LeBlanc, M. R., R. J. Dalter, and R. N. Boisvert. "Allocation of United States Coal Production to Meet Future Energy Needs." *Land Econ.* 54(1978):316–36.

Libbin, J. D., and M. D. Boehlje. "Interregional Structur of the U.S. Coal Economy." *Amer. J. Agr. Econ* 59(1977):456–66.

Schuh, G. E. "An Econometric Investigation of the Market for Hired Labor in Agriculture." *J. Farm Econ* 46(1962):307–21.

Schuh, G. E., and J. R. Leeds. "A Regional Analysis o the Demand for Hired Agricultural Labor." *Paper. and Proceedings Reg. Sci. Assoc.* 2(1963):295–308

Tyner, W. E., R. J. Kalter, and J. P. Wold. *Western Coal Promise or Problem*. Dep. Agr. Econ. A.E. Res 77-13, Cornell University, Aug. 1977.

Tyrchniewicz, E. W., and G. E. Schuh. "Regional Supply of Hired Labor to Agriculture." *J. Farm Econ.* 68(1966):537.

U.S. Department of Agriculture. *Agricultural Statistics*. Washington, D.C., selected years.

———. *Changes in Farm Production and Efficiency, 1977*. Statist. Bull. No. 581, Washington, D.C., 1977.

U.S. Department of Commerce, Bureau of the Census. *Statistical Abstracts of the United States*. Washington, D.C., selected issues.

U.S. Department of Commerce, Economic Development Administration. *State Quarterly Economic Developments* (by state). Washington, D.C., Jan. 1979.

U.S. Department of Labor. *Employment and Earnings, States and Areas, 1939–75*, Bull. 1370-12. Washington, D.C., 1977.

U.S. Department of Labor. Bureau of Labor Statistics. *Employment and Earnings*, vol. 26, no. 2. Washington, D.C., Feb. 1979 (periodical).

Formula Pricing in Five Commodity Marketing Systems

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Formula pricing has been a subject of concern in the food industry for twenty years, and perhaps longer (NCFM Report, p. 98). Formula pricing contracts involve prices on individual shipments or transactions which are tied directly, by formula, to a specific market price quotation. After buyers and sellers agree on the formula, subsequent transactions are routine and low in cost.

Formula pricing is a delegation of price discovery to those who negotiate prices. Consequently, the market mechanism and the price reporting services which generate the prices used in formula-priced contracts have an increasingly important and potentially more difficult burden placed upon them. Formula-pricing arrangements reduce the fraction of total supply entering into market price determination, and the resulting, more thinly traded markets may be more sensitive to erratic or manipulative influences on market prices or market price reports.[1] More recent concerns in the beef subsector are evidenced by several court cases, hearings before a House Small Business subcommittee, a special USDA Meat Pricing Task Force, and congressional bills focusing on meat industry pricing and price reporting systems (e.g., H.R. 91, 1979).

This study focuses on formula pricing in five commodity marketing systems where formula pricing was known or expected to be heavily used. We analyze the extent of formula pricing use in those markets, the incentives for or benefits of formula pricing, and the disadvantages and problems associated with formula pricing. Through a comparative analysis of formula pricing in the beef, pork, cheese, turkey, and egg markets, we offer some insights into the similarities and differences found in these markets and the sources of the controversy surrounding formula pricing systems. A few policy alternatives are then briefly considered.

The Extent of Formula Pricing

To determine the extent of formula pricing in these five marketing systems in 1978, we surveyed via personal or telephone interviews a high proportion of the largest firms involved in the markets where formula pricing was prevalent. In beef and pork, the large slaughter-processing firms surveyed accounted for 40% and 60% of the total market volume, respectively (Hayenga 1978, 1979b); the major cheese-marketing firms surveyed accounted for 85%–90% of the cheese consumed in the United States (Hayenga, NC-117 Work. Pap. No. 38); the firms surveyed in the turkey subsector accounted for about 66% of the industry's volume (Schrader and Lang). In addition, supplemental surveys of a smaller number of buyers and suppliers provided confirming evidence of the extent of formula-pricing use and supplemental views of the perceived advantages and problems. The egg market analysis draws upon a recently completed comprehensive study of coordination systems in the egg subsector (Schrader et al.) and Schrader's experience from years of work with the egg subsector. While the firms interviewed were not a random sample of the relevant populations, they accounted for a sufficiently large proportion of the relevant market volume that the survey results should provide a reasonable approximation of the extent to which various pricing systems are used in these markets.

Our studies revealed important differences in the use of formula pricing. These differences were not only between commodities, but at different levels of the marketing system and between closely related products at the same level of the commodity marketing system (see table 1).

Beef

The primary use of formula pricing in the beef subsector occurs in the beef carcass and wholesale cut markets. In a typical formula price contract, the quantity is established one to five days (sometimes longer) before shipment; the infrequently negotiated premium or discount is applied to the carcass price reported in the *National Provisioner* (the "Yellow Sheet") on the day prior to shipment.

Formula pricing is used in approximately 70% of the beef carcass sales which comprise 50%–60% of the output of beef slaughter-processing firms. In contrast, only 10%–20% of boxed beef primal and subprimal (including ground beef) sales are formula priced. Most boxed beef formula sales involve processed carcass units (with the price related to the Yellow Sheet carcass price), or ground beef (with the price based on the lean trim quotations). Be-

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[1] These issues are discussed in more detail in several places in the literature, including the National Commission on Food Marketing Summary Report and Technical Studies No. 1 and 2; Forker; Williams; Rogers and Voss.

Table 1. Pricing Systems in Five Commodity Subsectors, 1978

Product Submarket or Market Level	Beef: Beef Carcass	Beef: Boxed Beef	Pork: Fresh	Pork: Processed	Cheese: First Handler Transactions	Cheese: Packaged and Processed	Turkeys: Live	Turkeys: Processed	Eggs: Nest Run	Eggs: Graded and Packed
Sub-market share (%)	50+	40+	60	40	100	100	100	100	100	100
	(%)									
Intrafirm transfer[a]					20		65		35	≤5
Formula priced	70	10–20	40	5+	65–70	25–35	29	16	60	90
Negotiated prices	30	80–90	50	1–4	10–15	1–2	6	29	10[b]	5
Price list			10	90+		60–70		55		

[a] Involves vertically integrated cheese-production facilities, and a combination of vertically integrated production, producer-owned cooperatives, and cost-plus or service contracts in the turkey and egg subsectors.
[b] Includes direct sales of eggs to breakers, and resales among egg handlers; thus, there is some double counting in the nest run egg estimates.

cause boxed beef is the most rapidly growing segment of the beef market, it seems very likely that the negotiated portion of beef transactions could increase. However, the increasing boxed beef market share has been removing volume from the carcass beef market rapidly.

Pork

There has been a gradual shift toward more processing of pork by slaughter firms, with a corresponding shift in the mix of pricing systems employed. Slaughter-processors sell approximately 60% of their pork as fresh pork cuts (loins, Boston butts, fresh hams, bellies). Slightly less than 40% of slaughter-processor pork sales are processed pork (smoked or canned hams and picnics, bacon, lunch meats, frankfurters, sausage).

Formula-pricing arrangements are used in approximately 40% of fresh pork transactions, negotiated or offer-acceptance pricing systems in 50% of the transactions, and a daily price list is the primary pricing vehicle for the remaining 10% of fresh pork sales. The extent of formula pricing in fresh pork is approximately the same as that reported by the National Commission on Food Marketing in 1965.

In contrast, more than 90% of the processed pork sales are based upon a weekly price list for packer-branded products. Less than 10% of processed pork sales were "private label." More than half of the private label transactions are on a formula-pricing basis, and the remainder are priced using the branded price list minus advertising costs, or are individually negotiated transactions.

Overall, approximately 25% of all slaughter-processor pork sales are formula-priced, 35% of the prices are established at the time of the transaction through negotiation or offer-acceptance, and 40% of sales are priced via a daily or weekly packed price list.

Cheese

Formula pricing in the cheese industry is found in cheese purchases by large marketing firms (like Kraft and Borden) from many cheese manufacturing plants, and in sales arrangements between these large cheese-marketing firms and their retail, food service, and industrial customers. At each level, the standard formula-pricing arrangement utilizes the prevailing price at the National Cheese Exchange on the date of manufacture as the pricing base. While the National Cheese Exchange volume is less than 1% of the nation's cheese, it plays a major role in pricing 90% or more of the cheese sold by U.S. cheese-manufacturing plants to the large cheese-processing and marketing firms. These marketing firms also manufacture about 20% of their requirements, and import the remainder (6%–7% of sales) at negotiated prices. Thus, 85%–90% of cheese purchases by the large marketing firms are priced by formulas which may remain unchanged for three to twelve months.

Formula pricing plays a less important role in marketing firm sales to retail, food service, and industrial customers. Of the 50%–55% of cheese going through retail channels, approximately 60% is sold under a manufacturer brand, with a weekly manufacturer's price list as the standard pricing mechanism. On the 40% private label sales to retailers, some marketing firms use a price list that is essentially the branded price list less advertising and promotion costs; others use formula-priced selling arrangements.

The food service industry is the most rapidly

growing market for cheese, with 30%–40% of the cheese volume. A weekly or monthly price list is used for most sales through specialized food service distributors. Approximately 20%–30% of food service sales are directly negotiated, long-term, formula price arrangements with large-volume fast food chains which have special product specifications. Some formulas use the average Exchange price in the preceding months as the base price, so menu margins are based on known costs.

Industrial cheese sales, representing 10% of sales by cheese marketing firms, typically are specially formulated ingredients for frozen pizzas, frozen entrees, cheese-flavored products, and others. A high proportion of these sales are formula-priced arrangements with large industrial customers.

Thus, 25%–35% of the marketing firms' sales are formula-priced, based directly on the National Cheese Exchange prices. Another 5%–10% of sales are based on a price list so closely tied to the National Cheese Exchange prices that they implicitly are formula priced sales. Approximately 65%–70% of sales are based on a price list which is loosely related to the National Cheese Exchange (the raw material cost is an important influence in the pricing decision). Only 1%–2% of the sales of the marketing firms are spot sales on a negotiated basis; these often are sales of surplus inventories to another marketing firm through the National Cheese Exchange.

Turkeys

Approximately 65% of the live turkeys produced in the United States are produced and slaughtered by the producing firm, slaughtered by cooperatives, or produced under contracts (e.g., cost-plus or service fee contracts), where the ultimate producer payment is not directly tied to the spot market price. Nearly 30% of live turkeys are transferred from the grower to the processor under contract terms that relate the transaction price directly to the Urner-Barry or U.S. Department of Agriculture (USDA) market price quotation for frozen, ready-to-cook turkeys (though some contracts may have price floors, ceilings, or "sharing" formulas).

Turkey products include whole frozen turkey, turkey parts, and further processed products. Whole birds may be sold as plain Grade A (commodity) turkey or in self-basting, or otherwise differentiated form. Packer-branded whole birds and further processed products are most often price listed. Prices for sales of parts and fresh turkeys often are negotiated. Formula pricing is used mostly in the trading of private label or commodity turkey sales.

The market share of plain whole frozen turkey has declined to about 15%, and 20%–30% of that volume is formula-priced. Thus, the volume of negotiated trading in the product used as the base for pricing formulas at both the live and processed turkey levels may represent as little as 10% of turkey product sales.

Eggs

Eggs are formula-priced at two levels in the marketing system—the producer-first handler market for nest-run eggs, where the first handlers typically assemble, grade, and pack eggs (though some trading among the first handlers does occur), and the next market level where graded eggs are sold to the retail and food service sectors. In the nest-run or first handler market, 35% of the eggs are produced by vertically integrated firms. Sixty percent of the nest-run eggs are transferred to first handlers under long-term arrangements. Most contracts do not have a clear cut base price or premium established, just the handler's commitment to use his "best efforts" to achieve a "competitive" price for the producer. Yet, most handlers determine their payment by establishing a fairly stable discount from the pricing formula which they, in turn, have established with their primary customers. Thus, while the formula is not explicit in many cases, it is used implicitly in a large proportion of these transactions.

Very few nest-run egg sales involve negotiated prices. However, negotiated sales of nest-run eggs to egg breakers or among assemblers and first handlers are one point in the egg-marketing system where spot market price negotiations can be observed. These negotiated transactions (which include 1/2% of the nest-run egg volume, traded through the Egg Clearinghouse, Inc., an electronic exchange for nest-run eggs) involve approximately 10% of the nest-run egg volume.

Approximately 90% of graded eggs purchased by retailers and food service firms are acquired under long-term formula-pricing arrangements. In most cases, graded eggs that do not satisfy other customers' requirements are sold to egg breakers, also on a formula price basis. Approximately 5% of graded egg purchases are negotiated price transactions, primarily when suppliers build inventories in excess of their contract commitments, or retailers require extra volume for sales promotions. Thus, negotiated sales of graded eggs are sporadic and small in volume.

The egg price quotations typically used in formula-pricing arrangements in the eastern two-thirds of the United States at both the nest-run and graded-egg market levels are the New York graded-egg price quotations by the Urner-Barry *Producers' Price Current*. The USDA price quotation is used on the West Coast. Yet, the Urner-Barry reports do not represent any specific graded-egg market transactions; rather, the Urner-Barry report reflects changes in egg prices at other levels of the marketing system, changes in inventory levels, and other factors. The USDA price quotation does reflect prices for graded eggs paid by retailers.

Benefits and Problems of Formula Pricing

Respondents in the four marketing systems surveyed were asked to list the major advantages and disadvantages or problems associated with formula-pricing arrangements. The primary benefits or advantages which emerged from those interviews can be summarized as (*a*) assured market outlets or supply sources, especially when unique product formulations or perishable products are involved; (*b*) the greater quality assurance associated with continuing buyer-seller relationships; (*c*) the reduced risk of prices on forward sales or purchase arrangements looking bad relative to current market prices or competitors' prices at the time of delivery; and (*d*) improved physical marketing and transaction efficiency.

The relative importance of the benefits cited varied greatly in the markets studied. Firms dealing with highly perishable, standardized commodities (e.g., Choice, yield grade 3 beef carcasses, live turkeys, cheese) were quite concerned with assured market outlets or suppliers, as were firms requiring unique product specifications (e.g., unusual cheese or hamburger patty formulations or private label turkeys). Quality assurance was particularly important to firms with strong brand franchises, or to retail chain buyers of private label products. Retail chain buyers were particularly interested in forward purchases to assure the quantity required for features, with the assurance that the price would be established later at levels near competitors' prices, to avoid a significant competitive disadvantage. The low transaction cost and improved coordination of a continuing buyer-seller relationship which seldom requires extensive market information and negotiation skills was a frequently acknowledged benefit, especially to buyers and sellers who were not among the largest or smallest firms in the market, though that was seldom the primary reason given for starting the use of formula pricing.

Formula pricing lowers internal transaction costs and frees people from the task of negotiating prices. It facilitates close coordination of physical transfer of perishable commodities. Often, risks are shifted in a way that is desirable for both parties involved in a transaction. When desired quality and quantity can be assured satisfactorily only through long-term sales/purchase arrangements, formula pricing is an attractive pricing system. Both buyer and seller are assured a price in line with competitors' prices at the time of delivery. Firms using formula pricing for both raw material purchasing and product sales find that system useful in managing their margins. Many small firms feel that formula pricing reduces bargaining disparities between themselves and their larger, better informed suppliers or customers, enhancing their long-term viability. Formula pricing may be an alternative to a higher degree of vertical integration in some subsectors.

In some commodity-marketing systems, shifting to alternative pricing methods would be traumatic, with a high initial cost and perhaps higher cost per unit in the long run. For example, in the beef and pork markets, packers and retailers were asked to estimate the change in their transaction costs if they could not use formula pricing. Ten firms provided estimates which indicate that a ban on formula pricing would increase transactions cost in pork by as much as $5 million, and perhaps as much as $15 million annually for beef in the United States.

Formula pricing of cheese sold by cheese-manufacturing plants has been the standard way of doing business for so many years that most cheese plant managers could not conceive of any other way of pricing cheese. In the cheese market, long-term formula price contracts were sometimes used by marketing firms to develop new supplier capacity, yet not subject themselves to the risks associated with a pre-established price level. And some respondents felt that the alternative to formula pricing in that highly concentrated market would be the (undesirable) development of explicit price leadership by the leading firm(s). In general, there was a high level of satisfaction with the performance of the formula-pricing system and the thinly traded National Cheese Exchange in Green Bay, Wisconsin, that serves as the focal point in the price determination process at all levels of the cheese-marketing system in the United States.

A primary benefit of turkey formula pricing lies in the better coordination of production and processing. In many instances, neither the producer nor the processor desires to accept the risk of a price fixed at the time of production planning. The formula-priced contract allows for supply and market outlet assurance with price open.

Formula pricing of turkey products was least used by the largest and smallest processing firms. The largest firms felt that their own perspective on the appropriate market price was equal or superior to the market price quotations, and some felt that their product was sufficiently differentiated to be unique. The smallest also produced a differentiated product with loyal local consumers, so a price list was used instead of a price formula.

Formula pricing of eggs is seldom questioned by participants in the egg subsector. A National Egg Pricing System Study Committee (an industry group) in 1971 listed as one of their recommendations, "establishment of a national base price quotation system" (Rogers and Voss, p. 254). Most industry members do not wish to abandon formula pricing, but they do desire a better system of arriving at a base quote.

The basic benefit of formula pricing in the egg subsector is improved physical marketing efficiency, achieved through better coordination of producer-handler egg movement, and a stable routing system which is essential for efficient store-door delivery.

Survey respondents were asked their views on the disadvantages or problems associated with formula pricing. The primary problems which emergd

from these interviews can be summarized as (*a*) formula pricing's reduction of the firm's potential influence on its market price; (*b*) the absence in some markets of a well-accepted, sufficiently accurate or precise market price report to serve as a base for formula prices; (*c*) inability to capture fully, in a formula price arrangement, potential benefits from superior market information, forecasting, or negotiating skills; and (*d*) significant reduction of the potential number of customers or suppliers when some buyers or suppliers refuse to use formula price arrangements.

Few survey respondents mentioned, or perhaps were cognizant of, some additional implications of formula pricing. While there were occasional complaints in some markets about unreliable or inaccurate price reports (especially beef and eggs), most respondents did not relate those complaints to the reduced volume of negotiated trading which is a result of increased formula trading. In conjunction with increased processing and product differentiation (e.g., in beef, pork, and turkeys) that removes product volume from the "basic commodity" classification, the result is a more thinly traded market which serves as the source of the base price report for pricing formulas.

Large firms with a large number of formula-priced transactions may have a greater incentive and a greater potential of manipulating the market price or report through changes in their behavior. For example, some cheese market participants expressed concern about potential manipulation of the Cheese Exchange price by four or five Exchange members who trade a high proportion of the very small Exchange volume. However, upon closer examination, significant artificial price enhancement by any one firm acting alone for more than a very short period of time seems impractical because of the instantaneous communication of prices and the potential for countervailing reactions to price distortions by Exchange participants handling 85%–90% of the cheese in the country.

The ultimate problem of formula pricing is the potential for destruction of the negotiated market which provides the base price. Haverkamp (Hayenga 1979c, p. 103) has suggested that the use of formula pricing would level off as firms limit its use in response to a thinning negotiated market. Williams (Hayenga 1979c, pp. 88, 103) argues that formula pricing is likely to increase toward an equilibrium at which private reporting remains despite the lack of an adequate number of reportable trades in the negotiated market. The markets which we studied do not provide a clear basis for choice among those alternative hypotheses. However, a small number of the firms surveyed in the beef and pork markets indicated they were attempting to limit or reduce their use of formula pricing, though no clear trend emerged. In the cheese and egg markets where formula pricing is dominant, there is no indication that any significant reduction in formula pricing is occurring or contemplated. The situation in eggs is consistent with the Williams hypothesis; that is, the market is quoted at a level where almost no trades are negotiated unless special feature sales or excess inventories require unusual negotiated transactions to supplant the non-negotiated coordination mechanisms. The egg industry did recognize that a new mechanism was required to provide a better market price quotation and organized the Egg Clearinghouse, Inc., an electronic exchange, which brought some of the previously private trading into this public market arena. However, there has been no appreciable change in the amount of formula pricing in the egg market.

Summary and Conclusions

The extent of formula pricing in the five industries studied varied significantly, ranging from 90% or more of the cheese sold by cheese-manufacturing plants to large cheese-processing and marketing firms, to less than 10% for processed pork products.

Why is the incidence of formula pricing so different in these markets? While the answer is not entirely clear, we speculate that there are several contributing causes. The least amount of formula pricing is found in the packaged and processed cheese and processed pork markets where processor brand franchises are well established and administered price lists are feasible and preferred by the seller (and perhaps by the buyer, too). Only a small amount of boxed beef is formula-priced, partly because buyers dislike the price risk associated with wide ranges on boxed-beef price reports (which may be due to poor product standardization or imperfect market arbitrage on boxed beef cuts). But, the longer shelf life of boxed beef products (compared to beef carcasses) also may reduce meat packers' incentive to insure continuing buyer-seller relationships through formula-priced arrangements on boxed beef relative to beef carcasses. More fresh pork may be formula-priced than the comparable beef primal cuts because of pork's greater perishability, the greater perceived risk of using boxed beef pricing quotations, and the relatively recent entry of many boxed beef processors, which may have prevented the development of long-term relationships. Where close coordination of perishable products is required, as in eggs and turkeys, or price risk must be avoided by one party to the transaction (e.g., a small cheese plant), formula pricing or vertical integration is prevalent.

In our judgment, the degree of dissatisfaction expressed about market-pricing systems ranged from very little in the cheese industry to substantial in the carcass beef and egg markets, with more moderate levels of concern in the pork and turkey markets. Why would there be such a difference in the apparent level of satisfaction with the pricing systems used in these markets? The egg and cheese markets appear to have similar institutional characteristics, with thinly traded negotiated markets and

an extremely high incidence of formula pricing. We would conjecture that there may be several contributing factors. While the National Cheese Exchange trades less than 1% of the total cheese produced in the United States, nearly all major market participants are present, distortions are instantly communicated, and countering reactions are quick. Further, cheese production is concentrated in one region of the United States. Contrast this with the egg market, where production is widely dispersed throughout the country and where regions that are nearly self-sufficient sometimes shift temporarily from surplus to deficit regions. Thus, a price report at one location cannot reflect accurately the changing regional price patterns in the egg market, and stable formulas based upon the New York price report will get out of alignment with opportunity costs. Thus, we hypothesize that the occasional discrepancies between the reported market price and actual market prices in some regions may be the primary cause of the greater level of dissatisfaction with pricing formulas and reports in the egg market.

In contrast, the carcass beef market still has a high volume (though declining) of negotiated trades, so the dissatisfaction noted in that market probably cannot be attributed to a thinly traded market. Rather, the dissatisfaction seems to be related to the accuracy of the reported prices and suspicion regarding potential manipulation of reported prices via various methods. This might be related to the failure of many buyers and sellers to report fully and accurately their prices to the price reporting services and to the failure of price-reporting services to increase their reported product classes to include some high volume product streams that differ slightly in trim or grade from the current report categories. At the same time, there may be imperfect regional arbitrage in the carcass and boxed beef markets due to inadequate communication of market prices that are out of line, causing occasional regional price discrepancies relative to reported prices and prompting dissatisfaction among market participants. Further, the entire pricing process and the price reporting process is clearly more difficult for the outside observer to scrutinize and understand than the "open to the public" National Cheese Exchange where fears of the unknown might be better allayed.

Policy Implications

Our study of these markets has not revealed a need for major legislative remedy at this time. The benefits of formula pricing accruing to the firms using that pricing system generally seem to outweigh the perceived problems to those firms and to society. Perhaps the major concerns related to the use of formula prices are the suspicions regarding manipulated prices or unrepresentative price reports that are used in formula price arrangements. To date, convincing evidence supporting these suspicions has not been produced in the meat industry (USDA 1979, p. 25) or in the other markets we studied.[2] Elimination of formula pricing would lead to increased transactional cost and, probably, risk. Further, the resulting changes in competitive balance and structure in the markets we have studied may not be desirable.

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References

Forker, Olan D. *Price Determination Processes: Issues and Evaluation.* Washington, D.C.: U.S. Department of Agriculture FCS Info. 102, Sep. 1975.

Hayenga, Marvin L. (ed.). *Commodity Pricing Systems. Issues and Alternatives.* NC-117 Work. Pap. No. 39 Aug. 1979.

———. *Formula Pricing and Price Reporting Problems in the Markets for Beef and Pork.* NC-117 Work. Pap. No. 32, University of Wisconsin, May 1979a.

———. *Pork Pricing Systems: The Importance and Economic Impact of Formula Pricing.* NC-117 Work Pap. No. 37, University of Wisconsin, Aug. 1979b.

———. (ed.) *Pricing Problems in the Food Industry (With Emphasis on Thin Markets).* NC-117 Mono. 7, University of Wisconsin, Feb. 1979c.

———. *Pricing Systems in the Cheese Industry.* NC-117 Work. Pap. No. 38, University of Wisconsin, Aug 1979d.

———. *Vertical Coordination in the Beef Industry. Packer, Retailer and HRI Linkages.* NC-117 Work. Pap. No. 22, University of Wisconsin, Oct. 1978.

National Commission on Food Marketing (NCFM Report). *Food from Farmer to Consumer.* Washington, D.C., June 1966.

———. *Organization and Competition in the Livestock and Meat Industry.* Tech. Stud. No. 1, Washington, D.C., June 1966.

———. *Organization and Competition in the Poultry and Egg Industries.* Tech. Stud. No. 2, Washington, D.C., June 1966.

Rogers, George B., and Leonard A. Voss (eds.). *Readings on Egg Pricing.* MP-240, University of Missouri College of Agriculture, Dec. 1971.

Schrader, Lee F., and Mahlon G. Lang. "Pricing and Price Reporting Issues in the Turkey Subsector." *Marketing Information and Price Reporting Issues in the Food and Agricultural Sector,* ed. M. Hayenga, A.C. Johnson, and B. Marion. NC-117 Mono., University of Wisconsin, forthcoming.

———. *Turkey Pricing in the United States.* Purdue University Agr. Exp. Sta. Bull. No. 275, Apr. 1980.

Schrader, Lee F., Henry E. Larzelere, George B. Rogers, and Olan D. Forker. *The Egg Subsector of U.S. Ag-*

[2] There is currently a civil court action alleging that the Urner-Barry egg price report is not representative of egg market prices. *Sunnyside Eggs, Inc., et al.,* v. *Urner-Barry Publications Inc.,* U.S. District Court of the Northern District of Georgia, Atlanta Division.

riculture: A Review of Organization and Performance. NC-117 Mono. 6, University of Wisconsin, June 1978.

U.S. Department of Agriculture. *Report of the Secretary's Meat Pricing Task Force*. Washington, D.C., 15 June 1979.

U.S. Department of Agriculture, Agricultural Marketing Service. Packers and Stockyards Program. *Beef Pricing Report*. Washington, D.C., Dec. 1978.

Williams, Willard F. "Meat Industry Pricing Practices." Paper presented to the Meat Pricing Task Force, Washington, D.C., May 1979.

Marketing Alternatives and Resource Allocation: Case Studies of Collective Bargaining

Mahlon G. Lang

Agricultural economists are concerned with vertical coordination in commodity subsectors. This term was popularized by the work of Mighell and Jones, whose definition of vertical coordination is most commonly cited. "It includes all the ways of harmonizing the successive vertical steps, or stages, of production and marketing. Vertical coordination may be accomplished through the marketing price system, vertical integration, contracting, cooperation, or any other means, separately or in combination. There is always some kind of vertical coordination if any production takes place" (p. 4).

Mighell and Jones suggest that some mechanisms may bring about "better" coordination than others. In *Marketing Alternatives for Agriculture: Is There A Better Way?* several coordination mechanisms are described and discussed in terms of their possible consequences. The work edited by Marion is concerned with the definition of vertical coordination and describes coordination practices in various commodity subsectors.

Definitional and descriptive work is essential to informed public choice regarding the selection of coordination alternatives. But a need remains to develop and apply theory to the comparison of alternative coordination mechanisms.

General economists have made contributions which would aid such comparisons. In his seminal article, "The Nature of the Firm," Coase explained that the existence of the firm was predicated on economies of internal contracting as opposed to external, market transactions. Succeeding theoretical work focused on inter- and intrafirm coordination comparisons (Williamson) and on intrafirm coordination itself (Cyert and March). But the concept of market coordination has been treated as datum (Lowe), largely ignoring variations in the institutional setting of the market. Exceptions are seen in the literature of imperfect competition and industrial organization. These focus largely on market structure (narrowly defined) and its effects on allocative efficiency.

But Williamson's recent analysis of interfirm and intrafirm coordination offers a means of comparing resource allocation in different institutional settings. Williamson identifies conditions under which markets lead to greater allocative efficiency than do intrafirm decisions and vice versa. His work is drawn upon to interpret empirical observations reported in this article.

This analysis is born of concern that research on market coordination alternatives has neither drawn on this literature nor taken its own steps to develop a theory of vertical coordination. Inductive research (descriptive and definitional), while essential, has yet to produce general results which facilitate comparisons of coordination alternatives.

This article does not purport to construct a theory of vertical coordination. Rather, it is intended to provide a "building block," many of which are needed to construct such a theory.

The analysis has three specific objectives. The first is to demonstrate qualitative differences in the resource allocation consequences of independent contracting and collective bargaining in vegetable product markets. The second is to demonstrate that at least one dimension of the vertical coordination problem (minimization of joint costs of risk) can be addressed in the context of neoclassical theory. The third is to demonstrate that existing theory can be used to explain these qualitative differences.

The approach has four steps. The first is to present a hypothesis regarding risk allocation and joint cost minimization between collective bargaining associations and food processors. The second is to relate research findings and case studies of contract revisions induced by collective bargaining, each of which supports the hypothesis. Step three is to analyze the resource allocation consequences of the contract revisions. The final step is to interpret these consequences in terms of existing theory.

A Hypothesis

It is popular to assume that collective bargaining is a zero-sum game. A necessary condition for such an assumption is profit-maximizing behavior by the firms involved.

The assumption of profit maximization has been challenged by Cyert and March, whose observation of "organizational slack" in concentrated industries led them to argue that such firms may forego

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pecuniary efficiencies to maintain good relations among managers, with employees, and among functional divisions of the firm such as procurement, production, sales, and others (pp. 36–38). Liebenstein explains the consequences of such behavior in his classic article on "*X*-efficiency." Where there exists organizational slack, firms need not "operate on an outer-bound production possibility surface consistent with their resources. Rather they work on a production surface that is well within their outer bound. This means that for a variety of reasons people and organizations normally work neither as hard nor as effectively as they could. In situations where competitive pressure is light, many people will trade the disutility of greater effort, of search, and the control of other peoples' activity for the utility of feeling less pressure and better interpersonal relations" (p. 413).

While organizational slack and *X*-inefficiency may characterize firms in concentrated industries, various pressures may discipline the firm to reduce its costs by "taking up slack." Such pressure may appear in the form of changing management, increasing costs, falling demand, and other factors. It may also appear in the exercise of countervailing power through collective bargaining. *X*-inefficiency may appear in the form of misallocated marketing functions between vertical stages in a marketing channel.

Even in relatively competitive markets such misallocation is present. Baldwin and Hill, for example, concluded that farmers had overinvested in grain-drying capacity. Country elevators, they concluded, could perform the function at a lower unit cost than could farmers. The effect was to prevent the farmers and elevator operators from minimizing joint costs. If such phenomena occur in relatively competitive grain markets, similar occurrences in concentrated markets would be unsurprising and consistent with organizational slack and *X*-inefficiency.

Vegetable product markets are spatially oligopsonistic (Lang). Further, the most common coordination mechanisms are individual contracting and collective contract bargaining. The one-time contract offer by a vegetable processor can be viewed as a compact message. Conversely, collective bargaining while time consuming and complex, involves more discussion of nonprice contract terms. (In an analysis too extensive for discussion here, Hurwicz compares the resource allocation properties of a price mechanism—analogous to one-time contract offers—and a "greed process"—analogous to collective contract bargaining.) Iterative bids, offers, and counter-offers focus more attention on each dimension of a transaction than that expected under individual contracting.

Collective bargaining is expected to bring more information to bear on the contracting process and to bring pressure to bear on organizational slack. If so, the process may lead to the reallocation of marketing functions between growers and processors such that incentives to minimize joint costs are greater than they are under independent contracting.

These observations led the author to test the hypothesis that collective bargaining, as opposed to independent contracting, can and does increase incentives or opportunities to minimize joint costs of vegetable producers and processors. The following empirical observations support this hypothesis.

Contract Revisions and Collective Bargaining: Case Studies

A nation-wide mail survey of all fruit and vegetable bargaining associations was conducted. One aim of the survey was to identify terms of trade incorporated in contracts as a result of collective action. The survey received responses from thirty-three of thirty-six associations known to be bargaining for vegetable crops. Among terms added to contracts (and the number of associations adding such terms) were those relating to quality measurement procedures (13), delivery schedules (11), raw product handling procedures (10), by-passed acreage (22), and rights and responsibilities during production (18). A total of twenty types of terms were added as a result of collective action. An implicit aim of changing terms of trade is the Pareto-better goal of reducing joint costs. Otherwise, there would be no point in making such changes. Bargaining would be a zero-sum game. Any change in nonprice terms of trade would be reflected in the price of the commodity over which negotiations take place. Given parity of bargaining power, a cost would simply shift from one party to the other and there would be a corresponding change in exchange price.

To clarify the nature of contract revisions, their effects on incentives for participants, and their effects on resource allocation, personal interviews were conducted with managers initially surveyed by mail. The interviews provided many illustrations of terms collectively negotiated to shift the incidence of costs. Five such cases are outlined below. Each illustrates a shift in responsibility from grower to handler when the handler appears to be in the best position to minimize the relevant joint cost.

Case I

When delivered from grower to plant, sugar beets sometimes remain in receiving yards until shrinkage reduces their value in use. At one time, all shrinkage was charged to growers even though it took place after delivery. Processors, who controlled the beets after delivery, had no immediate incentive to prevent or reduce shrinkage. A grower association negotiated a maximum dockage for shrinkage. Any shrinkage of more than 5% resulted in a net loss to the processing firm. The firm's reaction was to adopt an improved storage technology for the beets. The use of canopies on piles of beets and the

use of vents in the same piles reduced shrinkage and maintained desired temperatures.

Case II

In the past, pea growers were docked for split or damaged peas in their crop. Splits and other forms of damage are caused by rapid combine harvesting. Combines are owned by processors and operated by their employees.

The Western Washington Farm Crops Association negotiated the elimination of dockage for split peas. The incentive to control defects was placed on the processor who could control the damage rate. Processors now have an immediate incentive to see that combines are operated at speeds which equate marginal benefit of rapid harvesting with the marginal cost of damage to peas. They bore no immediate incentive to do so prior to the contract revision.

Case III

Contracts between processors and growers of peas, sweet corn, lima beans, and other crops frequently include a clause which provides the contracting firm an option not to harvest a field if it is too dry or otherwise unsuitable for harvest. A serious charge in connection with this practice is that processors contract acreage in excess of anticipated needs, thereby reducing the risk of short supplies. Some growers allege that if, at harvest, the processor discovers that he has overcontracted, he becomes arbitrary in deciding how much acreage is suitable for harvest and chooses to bypass acreage suitable for harvest.

Whether the clause actually is used in this way is not at issue. At issue is the fact that decision control with respect to bypassed acreage is held by the processor while the consequences of his decision inflict financial loss on the grower.

Growers were understandably unhappy with this practice. Through collective bargaining, they have shifted all or part of the risk back to processors. In one case, growers and processors contribute to a pool used to compensate growers whose crops are bypassed. In others, processors are required to cover production costs incurred by growers.

These changes do not eliminate the practice of passing acreage. They do provide the handler with a direct incentive to equate the marginal benefits and costs of overcontracting and bypassing acreage.

Case IV

The Potato Growers of Idaho negotiated to refine the quality incentive provisions of contracts with potato processors. Contracts signed by growers with some processors have long included a "bruise free" provision. But growers charged that many of the potato bruises for which they were discounted resulted from rough handling at the plant. To avoid discounts for recent bruises, growers negotiated a "recent bruise" provision. This required the adaptation of existing technology to distinguish old bruises from new bruises. This made processors accountable for new bruises and led to specific changes in handling practices at the plant. The distance potatoes drop when unloaded from trucks has been significantly reduced. As a result, the number of recent bruises attributable to handling has also been reduced.

Case V

Ohio tomato growers waited in long lines to deliver their product to processors. Because growers bore the cost of a "floating inventory," processors had no incentive to increase receiving facilities or extend hours. They benefited from a steady flow of growers anxious to deliver their crops and return to the field. The Ohio Agricultural Marketing Association negotiated demurrage charges for growers who were delayed, thereby shifting responsibility for reducing delivery time. This created an incentive for handlers to reduce waiting time for growers. Delivery coordination was improved.

Another change in coordination of the quantity and timing of tomato deliveries merits note. Growers and handlers negotiated a rate of delivery per acre per day. This reduced the probability of excessive deliveries for existing facilities. Previously, when excesses were delivered, the grower wasted time and absorbed product loss. In the absence of a specified daily quantity for all growers, individual growers had no guarantee that their tomatoes would be accepted on any given day. Tomatoes are now shipped with confidence that they will be more readily received.

A minimum quantity to be purchased by the processors also was negotiated in Ohio. Tomato contracts specify a date before which the processor will not close down. Given this guide, the grower can better plan both planting and harvest.

In each case the incidence of a joint cost was shifted from grower to processor. Examples could be cited where the cost was shifted from processsor to grower. If either party could manage the specific cost equally well, it would make no difference from a resource allocation or economic welfare point of view who were to do so. The case studies would offer no evidence of qualitative differences in the resource allocation consequences of collective bargaining and individual contracting.

In fact, each case demonstrates a change in incentives which, theory suggests, would lead to an allocation of resources different from that expected under independent contracting. The use of canopies for sugar beets and different receiving procedures for potatoes and tomatoes resulted directly from incentives created by the revision of contracts.

In each case, a risk situation leads to added costs of production and/or marketing. Imperfect knowledge regarding the rate and level of processing re-

sults in potential shrinkage in sugar beets, damage to peas in harvesting, passed acreage, potatoes bruised in handling, and demurrage in the delivery of tomatoes. In every case, growers were penalized for the effects of this risk. But in every case, the processor knows better than growers what processing rates will be. Therefore, the processor is in a position to control the risk situation and to equate the marginal benefits and costs of holding beets, damaging peas, passing acreage, bruising potatoes, and delaying deliveries of tomatoes. The grower has no such control and has less knowledge of the risk situation than the processor. The minimization of joint costs is therefore more likely when the processor directly bears such costs.

Resource Allocation Consequences

The fundamental argument is that contract revisions induced by collective bargaining lead to a different allocation of resources than did the prior contracts. This section analyzes those consequences.

Conceptually, the same contract revision is involved in each case. In general terms, the cost of risk is shifted from the grower to the processor, who can better manage it. Thus, analysis of a specific case can be readily applied to the other cases.

Prior to the contract revision discussed in Case II, processors discounted growers for peas damaged during harvest. Growers bore the cost of damage to peas even though processors were more aware of the relative importance and benefits of rapid harvesting.

The effect of the contract revision is reflected in figure 1.[1]

In figure 1, S_1 is the supply curve when growers are discounted for peas damaged by rapid harvesting; S_2 is the supply curve when those growers are not charged for such damage. Growers will contract a given number of acres at a lower nominal price per ton when not discounted for damage. Demand, D_1, is the marginal value product (MVP) per acre of peas under the original contract. Equilibrium price and quantity are P_1 and Q_1; D_2 is the demand curve (MVP) for pea acreage if processors absorb the cost of damage to peas and if the cost of pea damage is the same when borne by processors as when borne by growers. In that case, equilibrium quantity (Q_1) is unchanged as is the net contract price (although the nominal contract price drops from P_1 to P_2).

But the processor knows more about the expected speed of harvesting than does the grower.

[1] The reader who expects a quantitative measure of the consequences of these changes will be disappointed. The goal of this article is only to show the direction of the resulting change in resource allocation and the creation of an incentive to change. Measurement of those changes would involve a massive control problem with no guarantee of adding useful information to the analysis.

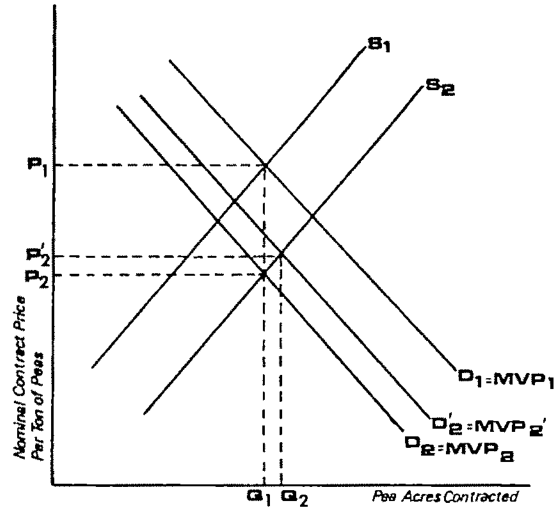

Figure 1. The effect of contract revisions to reallocate risk

Therefore, his cost of risk in managing the damage is lower than is the cost of risk faced by the grower. This is because the grower must estimate the level of damage, and therefore total discounts, on the basis of past experience. Thus, for a given level of output, $S_1 - S_2$, the amount the grower discounts a contract for expected damage, is greater than $D_1 - D_2$, the amount by which the processor discounts a contract for the expected cost of damage.

Thus, the actual demand curve (D'_2) would lie below D_1 but above D_2. Assuming that negotiators secure compensation for a higher MVP per contracted acre, equilibrium quantity will rise from Q_1 to Q_2. Because this is a partial equilibrium analysis, the effect of an increase in total supply on the level of retail price and its negative effect on MVP are not known.

Interpretation

The existence of information asymmetries in markets for processing vegetables suggests that certain joint costs will be minimized when borne by the party possessing the most information. In some cases these asymmetries are maintained because of information impactedness.

According to Williamson, "(Information impactedness) . . . exists in circumstances in which one of the parties to an exchange is much better informed than is the other regarding underlying conditions germane to the trade, and the second party cannot achieve information parity except at great cost—because he cannot rely on the first party to disclose the information in a fully candid manner" (p. 14).

This concept applies in Cases II and III. Processors, because they have greater access to demand information than growers, are in a better position to foresee the need for rapid harvesting (Case

II) than are growers, who can only estimate crop damage and the resulting discounts on the basis of past experience. For the same reason, processors can better foresee the likelihood of passing acreage (Case III) than can the growers, who would therefore discount more for the risk with respect to passed acreage.

In both cases the processor has an incentive to withhold information affecting likely harvesting procedures in order to maintain flexibility (Case III) or to avoid pressuring employees (Case II) during a hectic period. Such an intraseason incentive may lead processors to absorb higher pecuniary costs on an interseasonal basis.

But it is not clear in Cases I, IV, and V that processors could benefit by withholding information on the demand for sugar beets, potatoes, and tomatoes. In those cases, it is simply costly for growers to achieve information parity with processors. It is more difficult for producers than for processors to use information on expected processing rates to minimize joint costs.

Indeed, Phillips and his colleagues have argued, in the case of processing-potato markets (pp. 16–20), that it is impossible for growers to achieve information parity with processors. Phillips concludes that growers have no access, for example, to information on processing costs, marketing costs, or selected components of carryover and processed stock movement (p. 17). Further, neither the inventory position of individual firms nor their packing intentions are accessible to growers.

The processor's knowledge of the demand situation suggests that he is in a better position to manage the cost of demand-related risk than are growers. Growers must discount their expected returns because of this risk and do so on the basis of sketchy and sometimes inaccessible demand information.

One effect of collective bargaining in agricultural product markets has been to create incentives to minimize joint costs where information asymmetries exist. But the above is a partial equilibrium analysis. While it concludes that the revised contracts are preferable to the others in terms of economic performance, it does not address the comparative costs of coordination mechanisms. It ignores the possibility that collective bargaining involves higher transactions costs and greater buyer or seller alienation than does individual contracting. At the same time, there is no reason to believe that such costs are any lower for individual contracting.

In short, the analysis does not compare the two coordination mechanisms in terms of all dimensions of market performance. Its goal is, rather, to document fundamental differences in the resource allocation consequences of market alternatives. To this end, the following discussion explains why processors may fail to write least-cost contracts and, therefore, why collective bargaining or other forces would have been required to secure the contract revisions.

The neoclassical, profit-maximizing firm would minimize joint costs of food production and processing. Even in imperfect markets, as in vegetable product markets, the local monopsonist would increase his profits by writing voluntarily the contracts negotiated by growers. By rewriting contracts, the monopsonist could have contracted greater tonnage at the same price per acre.

In spite of this opportunity, the firms in the cases studied did not make these changes without the pressure of collective bargaining. The most appealing explanation begins with the claim of "organizational slack" suggested by Cyert and March. Managers may fail to pressure workers in receiving yards when they know they could receive tomatoes faster or handle potatoes more carefully. They may not discourage procurement personnel from overcontracting pea acreage nor caution machinery operators against harvesting too rapidly.

Thus, the original contracts may be least-cost from the point of view of the processing firm's manager. In the absence of pressure to do so, the manager may choose to avoid the frustration and friction required to reduce pecuniary costs of product handling and processing.

The consequences of such behavior are described by Liebenstein as "X-inefficiency." Processors may sacrifice greater long-term productive efficiency for the flexibility they are afforded on an intraseasonal basis. As argued in the analysis, the processor's greater knowledge of demand conditions (information asymmetry) may provide him with such flexibility.

When few buyers are present and there exists uncertainty with respect to packing intentions, buyers can exploit information impactedness (Williamson) to maintain uncertainty above what it need be for sellers. In so doing, processors may negotiate more favorable contract terms.

Organizational slack and X-inefficiency explain why processors may fail to write least-cost contracts. But there is no reason to believe that only collective bargaining could achieve these results. Many forces could lead the firm to reduce slack and move toward its production possibilities surface. But it is not clear that all such pressures would lead the firm to write contracts that foreclose its option to exploit information asymmetries. The firm may, in fact, rely more heavily on such short-run advantages in times of economic stress. Vertical integration or some form of countervailing power may be the only means of eliminating such obstacles to the reduction of joint costs.

Summary and Conclusions

This note examines case studies of contract revisions prompted by collective bargaining, analyzes their resource allocation consequences, and offers an explanation of why those revisions did not come about in the absence of collective bargaining. It

concludes that the revisions led to a reduction in joint costs of production and processing and argues that collective bargaining was one of several factors which may have prompted contract revisions.

These findings support the claim that there are fundamental differences in the resource allocation consequences of alternative vertical coordination mechanisms. They do not permit a conclusion that collective bargaining is necessarily a desirable alternative. They do offer evidence that one dimension of coordination may be improved through collective action.

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References

Baldwin, E. Dean, and Lowell D. Hill. "Estimating a Theoretical Contract Curve between Vertical Stages in the Illinois Grain Industry." *Amer. J. Agr. Econ.* 57(1975):74–82.

Coase, R. L. "The Nature of the Firm." *Economica N.S.* 4(1937):386–405.

Cyert, R. M., and J. G. March. *A Behavioral Theory of the Firm.* Englewood Cliffs, N.J.: Prentice-Hall, 1963.

Hurwicz, L. "Optimality and Informational Efficiency in Resource Allocation Processes." *A.E.A. Readings in Welfare Economics,* ed. K. Arrow and T. Scitovsky. Homewood, Ill.: Richard D. Irwin, 1969.

Lang, M. G. "Structure, Conduct and Performance in Agricultural Markets Characterized by Collective Bargaining." *Agricultural Cooperatives and the Public Interest.* N.C. Project 117, Mono. No. 4, University of Wisconsin, Sep. 1978.

Liebenstein, Harvey. "Allocative Efficiency vs. X-Efficiency." *Amer. Econ. Rev.* 56(1966):392–415.

Lowe, Adolph. "Toward A Science of Political Economics." *Economic Means and Social Ends,* ed. R. L. Heilbroner. Englewood Cliffs, N.J.: Prentice-Hall, 1969.

Marion, Bruce, ed. *Coordination and Exchange in Agricultural Subsectors.* N.C. Project NC-117, Mono. 2, University of Wisconsin, Jan. 1976.

Marketing Alternatives for Agriculture: Is There a Better Way? National Public Policy Education Committee Pub. No. 7, Cornell University, Nov. 1976.

Mighell, R. L., and L. A. Jones. *Vertical Coordination in Agriculture.* Washington, D.C.: USDA ERS-19, Feb. 1963.

Phillips, M. J., et al. "Processed Potato Growers' Associations: Information and Organization Needs." Washington, D.C.: USDA-FCS-34, Jan. 1977.

Williamson, O. E. *Markets and Hierarchies: Analysis and Antitrust Implications.* New York: Free Press, 1975.

Relationship between Two Price Quotes for Eggs

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Most transfers of shell eggs at all levels of the marketing channel from the production to the retail level are priced by formula based on published market quotations. Most pricing formulas in the U.S. east of the Rocky Mountains are based on prices quoted in *Producers' Price-Current*. West coast egg-pricing formulas most often use quotes by the U.S. Department of Agriculture's *Poultry Market News*.

The pervasive use of formula-pricing results in a thinly traded cash market and focuses attention on the price quotes. The validity and accuracy of quotes are major concerns of the trade. The problems of egg pricing are documented by Rogers and Voss and by Schrader, Larzelere, Rogers and Forker. The desire on the part of the trade for a means to facilitate price discovery and price reporting for eggs motivated the establishment of Egg Clearinghouse, Inc. (ECI). ECI is a cash exchange trading gradable nest-run eggs, where trades are matched by computer with the product moving directly from seller to buyer once a trade has been completed.

Trading on ECI has been thin, representing less than 0.5% of all eggs produced in 1978. Yet trades on ECI and Defense Personnel Support Center purchases represent the only transactions for which quality and delivery are clearly specified and for which prices are available to the public. Other transactions are known to participants and, to some extent, to Urner Barry or USDA reporters. Both Urner Barry and *Market News* report prices paid by retailers for cartoned eggs; however, these prices usually are determined by formula using a prior quotation.

Much of the trading on ECI represents trading among grading and packing firms to correct short-term imbalances. As such, these relatively few trades may represent the marginal price-making transactions. The quality specifications are such that only eggs suitable for cartoning for table use are acceptable for delivery in the gradable nest-run classes.

A committee, the Egg Market Evaluation Committee (EMEC), translates the trades, bids, and offers on ECI into quotes representing the Midwest (delivered Chicago) and East (delivered New York) twice weekly.[1] The EMEC quotes are based primarily upon activity on ECI supplemented by information gathered from telephone contact with members of the egg trade and current *Market News* statistics. This supplementary information is used only when the activity on ECI provides insufficient information for a particular class or location (Stemberger, Grange, Schrader). The Urner Barry reporters place less emphasis on use of ECI information. Urner Barry stated in August 1977: "In the development of the Urner Barry Egg Quotations, we use three broad areas of information as follows: the trading on Egg Clearinghouse, our own telephone canvass, and related information such as purchases by the Defense Department and other government units along with the various statistical information that is available." The UB spot market quote, which represents the base for most pricing formulas, has not been defined as representing a specific market level recently.

Many in the trade believe that prices based on ECI (such as the EMEC quote) should be used as the base for pricing formulas. Others defend present pricing practice, arguing that the added judgment and tempering of the "over reactions" to very short-term or regional imbalances reflected in ECI trading are more appropriate.

We suggest that if one series can be shown to lead the other, the leading series is the more accurate or sensitive indicator of equilibrium value. We assume that, in time, both quotes will change in the same direction as a change in the unobserved equilibrium values at all levels in the market. The two quotes do not represent the same level and one would expect there to be a market for processing services which would determine the difference between nest-run and graded, cartoned eggs. We do not have the data to model that relationship on a daily basis nor does the UB quote represent exactly a cartoned-egg level.

The lead lag relationship is further complicated by the fact that transfer-pricing formulas are based on the UB quote. We suggest that, if UB errs, transaction prices will follow and the resulting misallocation will persist until it becomes clear to the UB reporters that the quote must be changed. That is, if the UB quote is too high, users will take less than suppliers wish to sell, prices on ECI will be

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[1] Schrader is a member of EMEC.

offered down and, before the correction is complete, prices will be lower than otherwise would have been the case. Therefore, in a time period of about two or three weeks, errors in the UB quote may influence the level of prices on ECI.

If both quotes are equally accurate indicators of value change, one would not expect any lead or lag. If one is more sensitive, it would be expected to lead; however, any feedback through pricing formulas would be expected to result in a negative relation from a less accurate UB to a more sensitive EMEC quote. If UB is the more accurate, no negative feedback from EMEC to UB would be expected.

Review of Two Methods to Infer Causal Relations among Economic Time Series

The analysis applied in this paper is that generally discussed under the heading of Granger causality. The method provides a means to infer causal (or at least predictive) relations among two variables reported in a time series.[2] More specifically, we can say a variable X causes another variable Y, with respect to a given universe that includes at least X and Y if current values of Y can be better predicted by using past values of X than by not doing so, all other information in the universe (including past values of Y) being used in either case. The method has been applied in various studies; probably the most well known of these being Sims (1972) and Pierce.

In general, attempting to detect causality by analyzing cross-correlations or regressions of levels of Y on past levels of X and Y can be a difficult problem. In particular, the significance tests (t- and F-statistics) obtained from relating levels of highly autocorrelated series can be grossly overestimated, thus leading us to assert a causal relationship when none may exist. As an alternative to relating levels of series to detect causality, Haugh suggests that we deal with the innovations of each series.[3] That is, he suggests that we first remove all of the time-series properties from each series—i.e., filter both series using procedures of, say, Box and Jenkins. One can then cross-correlate the innovations of each series in order to infer any causal relationships. Pierce and Haugh demonstrate that variable X causes Y if the cross-correlations between the innovations from each transformed series are nonzero at positive lags—that is, current Y can be predicted by past X.

Other causal relationships involving two-way or feedback causality, instantaneous causality, and independence can be analyzed by these same cross-correlations. For example, if nonzero cross-correlations exist at both positive and negative lags, then a two-way or feedback relation exists between X and Y. Or, if no feedback exists, and if the cross-correlation is nonzero at a lag of zero, then there exists instantaneous causality.

The actual test of these cross-correlations must, of course, be carried out with estimated cross-correlations. Such a test can be made using the U-statistic given by Haugh:

$$U_m = n \sum_{k=1}^{m} r_k^2,$$

where n refers to the number of observations on the innovations of X and Y, r_k^2 the squared cross-correlations at lag k, and m is an integer, greater than or equal to one, chosen large enough to include expected nonzero coefficients. Under the null hypothesis of series independence, the U-statistic is distributed chi-square with m degrees of freedom.

In assessing one-way causality using the Haugh approach, there is a bias associated with the U_m-statistic. In particular, once we reject the hypothesis of independence among the innovations of current X and future Y, the test of feedback using U_m is biased toward failing to reject the null hypothesis of independence. The general nature of this problem is discussed in Sims (1977).

As an alternative to Haugh's procedure, we can use the causality test proposed by Sims (1972). He suggests one prefilter each series (using a common prefilter) to remove autocorrelation in both series. The current values of one transformed series (call it y) are then regressed on past and future values of the other transformed series (call it x). If causality runs from x to y only, future values of x in this regression should have coefficients, as a group, insignificantly different from zero. The test of the null hypothesis of no influence can be carried out with the usual procedures—comparing the relative reduction in sums of squared errors with and without the future values of x in the regression. Under the null hypothesis of no influence, the appropriate test is an F-test, (we reject the hypothesis of no influence for large F-values).

This second test can also result in improper inference if the common prefilter is not sufficient to remove substantial autocorrelation in each series. This problem is discussed within the causality context in Pierce and Haugh. A more general description of the problem is given in Granger and Newbold.

Application of the Causality Tests to Empirical Price Quotes by Urner Barry and EMEC

We apply the causality tests to 1977–78 twice-weekly price quote data of Urner Barry and EMEC. Thus, we have 208 observations on each series. It should be noted that the UB series is a price repre-

[2] The word causality in this context is perhaps misused. The word predictability might be better substituted. However, given its widespread acceptance in the literature, we continue to use causality.

[3] Here "innovations" refers to that part of a series which cannot be predicted from its own past.

senting New York wholesale Grade A large eggs but not precisely defined; while the EMEC series represents an estimate of trading level of class I gradeable nest-run eggs delivered to the New York area.

The estimated autocorrelations and partial autocorrelations on each series are given in tables 1 and 2. The behaviors of these estimates are similar for both series. The autocorrelations tail-off; while the partial autocorrelations cut off at lag 2. Two possible options seem appropriate: either we can model the price quotes as a second-order autoregressive process or we can investigate a difference transformation to take into account a possible nonstationarity in the levels. We considered both options and chose the former. The filters applied to UB and EMEC data are given as

$$\text{UB: } (1 - 1.24B + .35B^2)(Y_t - 61) = U_t$$
$$\text{EMEC: } (1 - 1.30B + .40B^2)(X_t - 50) = V_t,$$

where U_t is the innovation of the UB (Y_t) series and V_t is the innovation of the EMEC (X_t) series.[4] Both models give a fairly high degree of fit ($R^2 > .90$). Autocorrelations of the innovations (U_t, V_t) are generally small. These along with the portmanteau "Q"-statistic are given in tables 3 and 4.[5] Under the null hypothesis of no serial correlation, the Q-statistic is distributed chi-square with 22 degrees of freedom. Our calculated Q in both cases is below the critical value of 33.9 at the .05 level of significance.

Following Haugh's procedure, we cross-correlated the innovations from each series. These are given in table 5. Applying the asymptotic standard deviation ($1/\sqrt{n} = .07$) we note individual cross-correlations are significant (using two standard deviations) at lags of −1, 0, +1, and +2. This suggests that there is some evidence of a two-way or feedback causality. That is, there is evidence that the innovations of EMEC explain and are explained by the innovations of UB.

The evidence of instantaneous causality—a significant cross-correlation at lag zero is consistent with our prior beliefs. The quotes represent very closely related concepts. Thus, we should see a positive cross-correlation at lag zero.

Further discussion of the causality patterns can be carried out using the U-statistics reported as test 1 in table 6. Here we have calculated values of U for various leads and lags. Before discussing these however, we should point out that we originally suspected direct leads and lags at low values—say one, two, or three. In addition, we suspected that feedback, if it existed, would be found running from UB to EMEC, at lags of about one month. That is, our suspicions were that the innovations in quotes would be zero if separated by more than eight or nine periods. Thus, we calculated U-statistics with

[4] B is a lag operator such that $(B^n)\, z_t = z_{t-n}$.

[5] The portmanteau statistic indicates overall deviations of a series from a random series. It is described in Box and Jenkins.

Table 1. Estimated Autocorrelations and Partial Autocorrelations of 1977–78 Twice-Weekly Price Quotation by Urner Barry

	Lags																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Auto	.89	.74	.62	.51	.41	.34	.29	.26	.24	.22	.19	.15	.12	.09	.06	.03	−.00	−.04	−.09	−.13	−.19	−.24	−.27	−.27
P.Auto	.89	−.23	.10	−.10	−.00	.06	.02	.04	.01	−.00	−.06	−.02	−.00	−.01	−.03	−.02	−.04	−.07	−.07	−.05	−.10	−.02	−.01	.05

Note: Standard errors at low lags are approximately .07.

Table 2. Estimated Autocorrelations and Partial Autocorrelations of 1977–78 Twice-Weekly Price Quotation by EMEC

	Lags																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Auto	.90	.76	.59	.43	.30	.21	.16	.15	.15	.14	.13	.13	.13	.11	.09	.06	.01	−.05	−.11	−.16	−.21	−.24	−.25	−.25
P. Auto	.90	−.24	−.19	−.04	.01	.13	.06	.05	−.09	−.02	.03	.07	.03	−.09	−.05	−.02	−.07	−.10	.02	−.07	−.07	.02	−.04	−.01

Note: Standard errors at low lags are approximately .07.

Table 3. Estimated Autocorrelations of the Residuals from the Estimated Filter $(1 - 1.24B + .35B^2)(Y_t - 61) = U_t$, Applied to 1977–78 Twice-Weekly Price Quotations by Urner Barry

Lags																								
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Q^a
.08	−.20	.10	.06	−.10	−.00	.06	−.03	−.01	.10	.06	−.02	−.00	.03	−.02	−.03	.03	.04	−.06	.05	.03	−.04	−.06	−.01	22.0

Note: Standard errors at low lags are approximately .07.
[a] Q is distributed χ^2 (22) under the hypothesis of series independence.

Table 4. Estimated Autocorrelations of the Residuals from the Estimated Filter $(1 - 1.30B + .40B^2)(X_t - 50) = V_t$, Applied to 1977–78 Twice-Weekly Price Quotations by EMEC

Lags																								
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Q^a
−.07	.11	.01	−.09	−.09	−.05	−.16	.12	−.01	.03	.01	−.01	.04	.06	−.06	.05	.10	−.04	.04	−.04	.01	.03	.01	−.05	22.2

Note: Standard errors at low lags are .07.
[a] Q is distributed χ^2 (22) under the hypothesis of series independence.

lags of three and nine periods in each direction. These statistics indicate rather strongly causality running from EMEC to UB. That is, for lags lasting no longer than a month UB seems to follow EMEC. Going back the other way, we find the evidence more questionable. In testing UB leading EMEC, we cannot reject the hypothesis of series independence at the 1% level; however we do reject this hypothesis at the 5% level.

The causality results based on Haugh's U-statistic should be viewed with caution, since there is a tendency to underestimate the significance level of U given one-way causality. As alternative evidence, we consider the Sims test which was briefly described above. Each price series was first transformed with the common prefilter $(1 - 1.27B + .37B^2)$. This filter ought to be sufficient to nearly prewhiten each series—as it closely resembles the empirical filters obtained above using Box and Jenkins' procedures. We tested causality running both ways (from EMEC to UB and vice versa). Again, leads and lags of three and nine periods were tested. More explicitly, we tested causality running from EMEC to UB in a single-equation ordinary least squares regression by regressing the transformed EMEC series on past and future values of the transformed UB series. We then reran the regression without the future values of the transformed UB series. If causality runs from UB to EMEC only (that is, EMEC does not cause UB) then the future values of UB in the regression will be insignificantly different from zero. The residual sums of squared errors are compared using the usual F-test. An analogous set of regressions was run to test causality from UB to EMEC.

The F-tests from these regressions are summarized in table 6 as test 2-*i* and *ii*. Test 2-*i* considers the null hypothesis that the entire set of regressors (past and future) have coefficients equal to zero, as a group. We reject this hypothesis in all cases—suggesting that there is dependence among the transformed values of the two egg quotes. Test 2-*ii* considers the hypothesis that the coefficients associated with the future values of the causal series are, as a group, not significantly different from zero.[6]

Failure to reject this null hypothesis is inconsistent with causality in the direction indicated in the table. That is, we reject the null hypothesis that the future values of UB have (as a group) no influence on current values of the EMEC quote. Thus, we cannot say that causality runs from UB to EMEC only. Alternatively, we can say causality runs from EMEC to UB. A similar statement cannot be made

[6] Similar statistical results were obtained by applying Sims' regression tests to series prefiltered with the separate empirical filters used in the Haugh procedure. We also investigated the Sims test using current values of the regressor in the Sims regression. That is, regressing y on past, current, and future values of x yields causal orderings similar to those obtained in test 2-*ii*. While Sims (1972, p. 545) did not suggest this alternative test, we investigated it for completeness.

Table 5. Cross-Correlations between the Innovations of Urner Barry and Egg Market Evaluation Committee Price Quotes

	Negative[a,c]									
Lags	0	−1	−2	−3	−4	−5	−6	−7	−8	−9
0–9	.36	.19	−.05	.06	−.13	.01	−.08	−.08	.09	.07
10–10	.05	.03	.03	.02	−.04	−.08	.05	.12	−.05	−.05
	Positive[b,c]									
Lags	0	1	2	3	4	5	6	7	8	9
0–9	.36	.26	.15	.12	−.01	−.06	−.11	−.01	.01	.08
10–10	.03	−.05	−.01	.05	.01	−.05	.13	.02	−.02	−.00

[a] EMEC lagging (or following) UB.
[b] UB lagging (or following) EMEC.
[c] $1/\sqrt{n} = .07$.

for causality running from UB to EMEC. We do not reject the hypothesis that future values of EMEC have coefficients as a group equal to zero.

The two tests are consistent and allow us to make some general statements. We can firmly reject the hypothesis that EMEC is passive, responding to the UB quote but not influencing it. This follows from the significant chi-square statistic in test 1 and the significant F-statistic in Test 2-*ii* in the EMEC → UB column of table 6. The results are also consistent with the hypothesis that UB is, at best, questionable in its influence on EMEC. That is, coefficients of the future values of EMEC in the regression of UB on past and future values of EMEC are, as a group, not significantly different from zero, at the 1% level. However, test 1, based on the cross-correlations, shows some evidence of feedback at the 5% level, however slight.

Discussion of Results

Our analyses indicate causality running from EMEC price quotes for class I gradable nest-run eggs in the current period to UB spot market quotes for large whites, one, two, and three quote periods into the future. These results are both important and interesting. Recall that EMEC quotes reflect primarily trading activity on the thinly traded ECI while UB quotes are said to be based on ECI trading and upon other information. Our results suggest that this additional information or tempering of price extremes may not serve to improve UB quote as an indicator of changes in the unobserved equilibrium.

The results indicate that the thinly traded ECI is a relatively accurate and sensitive indicator of changes in the equilibrium price of eggs. ECI does represent a residual market. As indicated above, firms offer eggs which have not sold to regular outlets at prevailing prices or bid for eggs needed to supply regular customers in excess of supplies at prevailing prices. Increasing or decreasing price to secure or dispose of the marginal load is the essence of price discovery. ECI gives the marginal load national exposure and quality specifications assure the quality dimension of price information from the exchange. This positive evidence of the relative accuracy and sensitivity of ECI price during the 1977–78 period is encouraging for the ECI concept and one would expect enhanced accuracy and sen-

Table 6. UB–EMEC Causality Detection Tests

	EMEC → UB		UB → EMEC	
	3 periods	9 periods	3 periods	9 periods
Test 1[b]	21.53*[a]	26.14*	8.69	1.751
Test 2: *i*[c]	6.87*	4.85*	9.78*	4.44*
ii[d]	9.75*	3.51*	1.88	1.42

[a] Single asterisk indicates rejection of null hypothesis at 1% level.
[b] Test 1 is the empirical Haugh U-statistic based on the cross-correlations of the innovations from separate empirical refilters. Tabular chi-squared values are $\chi^2_{.01}(3) = 11.3$ $\chi^2_{.01}(9) = 21.7$ $\chi^2_{.05}(3) = 7.81$ and $\chi^2_{.05}(9) = 16.91$. Empirical chi-squared values greater than these tabular values suggest we reject the null hypothesis of independence among the innovations.
[c] Test 2-*i* is the empirical F-statistic associated with the estimated coefficients of the entire regressions of past and future innovations in Sims' causality regression. The tabular F-values are $F_{.01}(6,200) = 2.90$ and $F_{.01}(18,188) = 1.98$. Empirical values of F greater than these tabular values suggest we reject the null hypothesis that the regression coefficients as a group are equal to zero.
[d] Test 2-*ii* is the empirical F-statistic associated with the test that the coefficients on the future innovations in the Sims regression are, as a group, equal to zero. The tabular F values are $F_{.01}(3,200) \approx 3.89$ and $F_{.01}(9,188) \approx 2.52$. Empirical values of F greater than these tabular values suggest we reject the hypothesis that the coefficients on these future innovations are, as a group, equal to zero.

sitivity from increased trading levels in evidence at this writing.

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References

Box, G. E. P., and G. M. Jenkins. *Time Series Analysis: Forecasting and Control.* San Francisco: Holden-Day, 1970.

Granger, C. W. J., and Paul Newbold. "Spurious Regressions in Econometrics." *J. Econometrics* 2 (1974):111–20.

Haugh, L. D. "The Identification of Time Series Interrelationships with Special Reference to Dynamic Regression Models." Ph.D. thesis, University of Wisconsin, 1972.

Pierce, D. A. "Relationships—and the Lack Thereof—between Economic Time Series, with Special Reference to Money and Interest Rates." *J. Amer. Statist. Assoc.* 72(1977):11–22.

Pierce, D. A., and L. D. Haugh. "Causality in Temporal Systems." *J. Econometrics* 5(1977):269–92.

Producers' Price Current, vol. 120, no. 163. Toms River, N.J.: Urner Barry Publications, 23 Aug. 1977.

Rogers, G. B., and L. A. Voss. *Readings on Egg Pricing.* MP 240 University of Missouri, Dec. 1971.

Sims, C. "Money, Income and Causality." *Amer. Econ. Rev.* 62(1972):542–52.

———. "Relationships—and the Lack Thereof—between Economic Time Series, with special Reference to Money and Interest Rates: Comment." *J. Amer. Statist. Assoc.* 72(1977):23–24.

Schrader, L. F., H. E. Larzelere, G. B. Rogers, and O. D. Forker. *The Egg Subsector of U.S. Agriculture: A Review of Organization and Performance.* NC Proj. 117, Mono. No. 6. Purdue University Agr. Exp. Sta., June 1978.

Stemberger, A., G. Grange, and L. Schrader. "How ECI Values Are Established by Egg Market Evaluation Committee." *Egg Industry.* Sea Isle, N.J.: Garden State Publishing Co., Sep. 1976.

U.S. Department of Agriculture. *Poultry Market News.* Washington, D.C., selected issues.

Economic Efficiency and Policy Comparisons

Mahlon George Lang

Empirical studies published in the *Journal* have used the concept of economic efficiency to compare policy alternatives. Hall and LeVeen present an "analysis . . . developed for the current debate over acreage restrictions in reclamation policy." The authors argue "that large farms generally have lower production costs and that restrictive policies may therefore have some impact on overall economic efficiency" (p. 589). Mann and Paulsen assess the "impact of restricting feed additives in livestock and poultry production." They conclude that "health risk reductions may be obtainable at a smaller loss in economic efficiency than previously suggested" (p. 47). The reader will recall colleagues' claims that particular regulations or policy proposals would result in a loss in economic efficiency.

The Meaning of Economic Efficiency in Use

The measures of economic efficiency implied in the cited articles are simply productive efficiency or the private, pecuniary unit cost of production. These measures are quite different from the concept of Pareto optimality, which is the only theoretical definition of economic efficiency. Further, the use of such measures to compare policy alternatives obscures the true nature of the public choice involved.

Any policy which restricts the use of productive factors or establishes conditions on production will, if it is a binding constraint, raise the pecuniary unit cost of production. When this measure is used, it is tautological that, assuming rational decisions, any such policy action will reduce economic efficiency.

In any public choice affecting food additives, pesticides, product safety, and such, the real policy question is: "What factors and products shall be allocated by market exchange?" Explicitly, "shall the cost of health risk resulting from the use of feed additives be considered by livestock producers?"

This question cannot be answered in terms of economic efficiency. As Schmid and Shaffer have said, "Economic theory provides a method of calculating positions of maximum efficiency or optimum advantage. . . . These calculations are valid, however, only within any given set of exchange system rules which defines the qualitative makeup of the inputs and outputs to be included" (p. 29).

Policy choices affecting the use of feed additives, acreage limitations in federal irrigation projects, and others are choices among exchange system rules and the qualitative makeup of inputs and outputs to be counted by the market. In the absence of actual compensation to those injured by policy choices, conclusions that such choices affect economic efficiency positively or negatively are wrong.

Kaldor, Hicks, and Scitovsky (Henderson and Quandt, p. 279) have suggested compensation criteria which accept potential, rather than actual, compensation to losers. But, as Henderson and Quandt point out, "nothing can be said about the social preferability of (allocation) A over (allocation) B in the absence of actual compensation unless one is willing to make additional value judgments" (p. 279).

Economic Efficiency in Theory

Production efficiency and economic efficiency are defined and discussed below. These definitions are used to analyze the concept of economic efficiency used in the articles cited earlier.[1]

Production Efficiency

Hall and LeVeen (pp. 589, 90, 91) claim a loss in "economic efficiency" owing to the 160-acre irrigation limit. But their definition of economic efficiency really corresponds to "the overall efficiency of the firm" (Farrell, p. 255).

For Farrell, production efficiency is the joint occurrence of technical efficiency and price efficiency. Technical efficiency is achieved when the minimum quantities of factors (X_1 and X_2) are used (in fixed proportions) to produce a given level of output (Y). Price efficiency is achieved when the ratio of factor prices is equal to the ratio of factor use.

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[1] The arguments developed here apply to numerous works in addition to those cited. There is general misuse of the concept of economic efficiency. This analysis does not question the importance, analyses, or value of the work by Hall and LeVeen and Mann and Paulsen. Their work is cited to analyze a term (economic efficiency), the misuse of which has substantive, but inappropriate policy implications.

The effect of enforcing a 160-acre irrigation limit, as measured by Hall and LeVeen, is to restrict each firm's use of a variable factor. If binding, this restriction precludes price efficiency and, therefore, firm efficiency with respect to the production of Y using X_1 and X_2 will not be achieved. Clearly, private pecuniary unit costs of production for Y will be higher when the use of a binding factor is restricted.

But this is not the same as a loss in economic efficiency. It is possible to achieve different economically efficient allocations of resources when different initial endowments of property rights shape market exchange. Under different definitions of property rights affecting factor use, the firm can still achieve overall productive efficiency with respect to the remaining variable factors of production. Each definition will raise or lower private, pecuniary costs of production depending on whether irrigated acreage limitations are enforced or irrigation water is publically subsidized in the first place as, in fact, it is. Thus, given each definition of property rights, productive efficiency would be achievable and consistent with economic efficiency depending on public goals with respect to the output of Y, the size distribution of commercial farms, and the opportunity cost of subsidizing irrigation initially.

For example, in (1) there are not restrictions on irrigated acreage because there is less concern with farm structure than is implied in (2), where irrigated acreage (X_2) is treated as a fixed factor. Given that X_2 is fixed, production efficiency

(1) $$Y = f(X_1, X_2/X_3 \ldots X_n),$$

(2) $$Y = f(X_1/X_2 \ldots X_n),$$

(3) $$Y = f(X_1/X_3 \ldots X_n),$$

with respect to variable factors can be achieved although (if X_2 is binding) at a lower level of Y than in (1). Similarly, if there were no public subsidy of irrigation water and it were simply not available, X_2 would drop out of the equation entirely as in (3). The potential for production efficiency with respect to variable factors would remain and the potential output of Y would be even lower than that suggested by (2).

Farrell's test of production efficiency can therefore be applied to variable factors in the context of any policy affecting the availability of factors. The test can be used to compare private pecuniary unit costs and the level of output Y under each policy. But the test cannot be used to compare these policies in terms of economic efficiency.

Economic Efficiency

As Henderson and Quandt indicate, "Pareto optimality provides a definition of the economic efficiency of allocations that serves as the basis for much of welfare economics" (p. 255). Alternative definitions of economic efficiency cannot be found in the literature. The same authors further observe that "changes which improve the positions of some individuals but cause a deterioration in those of others cannot be evaluated in terms of (economic) efficiency . . ." (p. 256). The studies cited above clearly imply that such changes can be evaluated in terms of economic efficiency.

Economic efficiency (Pareto optimality) in consumption, in production, and in general are clearly defined. Economic efficiency in consumption is defined by the equation of marginal rates of commodity substitution (MRCS) between consumers. Economic efficiency in production is defined by the equation of marginal rates of technical substitution (MRTS) between producers and between factors of production. Economic efficiency in general is defined by the point at which the marginal rate of commodity substitution (MRCS) for all consumers equals the MRTS between factors for all producers. Models of perfect competition define conditions under which producers will select such a point in response to relative prices defined by consumers engaged in the free exchange of commodities.

Two Theoretical Analyses Involving Pareto Efficiency

Two applications of the Pareto efficiency concept can more appropriately be used to analyze the feed additives issue addressed by Mann and Paulsen. The first application is a traditional analysis involving external economies and diseconomies. This approach analyzes the policy choice in a Pareto framework which shows the possibility of moving to a higher level of social welfare when the diseconomy is internalized. While consistent with Pareto efficiency, the first analysis does not frame the policy issue as accurately as does the second approach.

The second analysis involves the redefinition of factors and products. It demonstrates that the decision to restrict feed additives cannot be evaluated in terms of economic efficiency because it involves different combinations of factors and products. It analyzes the decision in a framework which shifts the structure of production possibilities and shows that the policy alternatives are not Pareto-comparable.

External Diseconomies

The use of feed additives by livestock producers is said to be an external diseconomy to the producers and consumers of good health. All costs of livestock production (which include the risk of poor health to meat consumers) are not internalized by livestock producers. This externality holds the price of livestock low relative to the price of good health. The result is a Pareto inefficient allocation of resources. (For proof, see Appendix.)

Mann and Paulsen make assertions about eco-

nomic efficiency consequences of restricting feed additives only with reference to livestock production. They treat health risk resulting from the use of feed additives as something that one trades off against economic efficiency. In fact, in a Pareto-efficiency context, the livestock output-health risk trade-off is an intimate part of the efficiency question. The economic efficiency of livestock production cannot be evaluated independent of the level of health risk.

The Redefinition of Factors and Products

The second approach to analysis of the feed additives issue views the related policy decision as a nonmarginal change affecting the entire structure of production possibilities. Thus, two Pareto-efficient allocations of resources are possible under restricted or unrestricted use of feed additives. Clearly these allocations cannot be compared in terms of economic efficiency.

Each set of market rules affecting factor use defines a production possibilities curve for the economy. Figure 1 depicts two such frontiers. Frontier F represents a simple economy which produces livestock and good health and permits unrestricted use of feed additives for livestock. Frontier F' represents an economy producing the same products under rules forbidding or restricting the use of additives.

As figure 1 indicates, a Pareto-efficient allocation of resources can be achieved under either definition of property rights represented by production possibilities frontiers F and F'. The redefinition of property rights amounts to a change in initial endowments (E_1 and E_2). These lead to different price relatives for factors and products. Social welfare functions SW_1 and SW_2, on which price relatives are presumed to identify at least one point, may be located as suggested in figure 2.

In this illustration, the unrestricted use of feed additives permits one person or group of persons to benefit greatly in terms of livestock (meat) consumption but the other person or group of persons gives up much "good health." Pareto-efficient allocations of resources are possible under either rule. But, in the absence of compensation for those who give up something in terms of health, the decision to restrict the use of feed additives and therefore the resulting resource allocation cannot be evaluated in terms of economic efficiency.

The potential normative burden associated with comparing these policy alternatives is better illustrated by transposing production possibilities frontiers F and F' (figure 1) into utility possibilities frontiers as was done by Mishan (1973, p. 751). Figure 2 shows two such utility frontiers. These define the levels of utility each production possibilities function would provide for two different consumers or two groups of consumers. The horizontal axis measures the utility acquired by consumer (group) A under each policy toward feed additives. This group clearly derives more utility from health relative to livestock than does consumer (group) B for which utility is measured on the vertical axis. A therefore derives more total

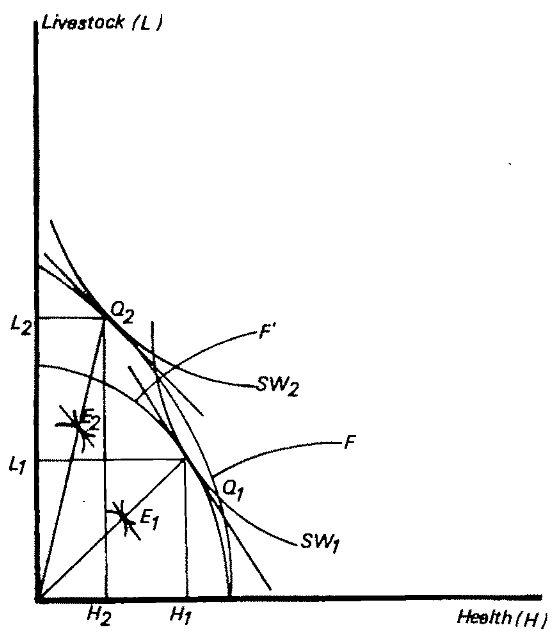

Figure 1. Pareto-efficient allocations under restrictive and nonrestricted policies with respect to feed additives

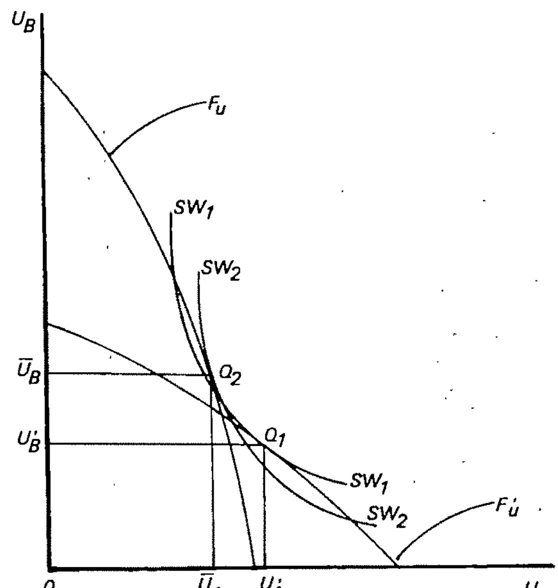

Figure 2. Mishan's two-person utility possibilities frontiers illustrating Scitovsky's Paradox

utility ($U'_A > U_A$) from the policy of restricting feed additives while B derives more total utility ($U_B > U'_B$) from the policy permitting the use of feed additives.

SW_1 is a community indifference curve (also transposed from fig. 1) which defines the Pareto-efficient allocation of resources when feed additives are restricted. SW_2 is the community indifference curve defining the Pareto efficient allocation of resources when feed additives are not restricted. Such curves give rise to Scitovsky's paradox (Mishan 1976, p. 394). The paradox arises as follows. Society can allocate its resources in a Pareto-optimal way at Q_2 in the case where feed additives are not restricted. But it is clear that Q_1, representing the Pareto-efficient solution under the policy which restricts feed additives, lies above the community indifference curve SW_2. However, if society restricts feed additives and if the resulting Pareto allocation is Q_1, it is clear that Q_2 lies above the indifference curve SW_1. The policies are not Pareto-comparable. Mishan's analysis of the paradox leads to a conclusion that "such cases are only resolvable by reducing them to a distributional ranking of the collections in question" (1973, p. 765). He further states, "In light of the above analysis, a conclusion that criteria based on potential Pareto comparability should be used with greater circumspection is hardly necessary" (p. 765).

Different initial endowments lead to different relative prices. These favor different people depending on their personal utility maps. Thus, the policy choice regarding feed additives cannot be unambiguously evaluated in a Pareto framework. A Pareto-efficient allocation of resources is possible given one definition of property rights (policy). But even in unambiguous (nonparadoxical) cases, unless there is compensation by gainers to losers, movement from one policy to the other cannot be compared. In the absence of a normative goal or decision rule, nothing in the training of economists can be used to determine which definition of property rights is best in the first place. There is nothing beyond impact analysis that the economist can contribute to the evaluation of these alternatives. The economist cannot compare policy alternatives in terms of economic efficiency.

This second approach to analysis more accurately reflects the nature of the policy choice than does a comparison of pecuniary price levels or even analysis of external diseconomies. The former is tautological and the latter assumes that relative prices are determined uniquely by consumers' and producers' actions in the market. While consumers' choices directly determine relative prices, policy choices determine the market rules within which those choices will be made. Thus, a different set of price relatives, a different combination of products, and a different income distribution will result under each policy alternative.

Therefore, price is a normative datum. The set of prices arrived at under one definition of property rights is a reflection of values underlying those property rights. Property rights issues arise from different sets of values which, if reflected in policy, lead to different Pareto-efficient allocations of resources.

To analyze a policy issue in the context of external diseconomies is to evaluate the policy choice in the context of one set of values. In fact, the policy choice is: Which set of values shall the market reflect?

Implications for Economists

Economists have drawn extensively on price-based (hence, normative) concepts to compare policy alternatives. These concepts include not only economic efficiency, but also marginal value product (as a measure of a factor's contribution to pecuniary output) and the concepts of producer and consumer surplus (as measures of welfare). The normative content of such concepts limits the ways in which the policy economist can apply analytics to the comparison of policy alternatives. This may leave him/her uneasy. As Boulding has said:

> We are strongly inbued today with the view that science should be *wertfrei*, and we believe that science has achieved its triumph precisely because it has escaped the swaddling clothes of moral judgment; it has only been able to take off into the vast universe of the "is" by escaping the treacherous launching pad of the "ought." Even economics, we learn in the history of thought, only became a science by escaping from the casuistry and moralizing of medieval thought. Who, indeed, would want to exchange the delicate rationality of the theory of an equilibrium price for the unoperational vaporings of a "just price" controversy? In the battle between mechanism and moralism generally mechanism has won hands down. . . . (pp. 117–18)

Economics, insofar as it addresses the fundamental economic (and policy) question of how scarce resources should be allocated among unlimited ends, has not escaped and, by definition, cannot escape the "launching pad of the ought." However methodologically attractive the use of price-based policy evaluation criteria, recognition that these criteria are inappropriate in such use demands adjustments by economists in their efforts to conduct policy analysis. Two possible adjustments are suggested below.

The first, and most logical adjustment is to compare nonmarginal policy changes in terms of their impacts on affected groups. That is, use the tools of economic analysis to identify the incidence of benefits and costs associated with policy alternatives. But it is essential that the analyst avoid the temptation to compare benefits to group A with costs to group B and then to conclude that one policy or the other is superior in terms of economic efficiency.

A second possible adjustment is for economists to give more attention to the design of policies and institutions which will achieve specified social and economic ends. The outlines of such an approach are provided in Lowe's appeal for an "instrumental economics," the nature of which is paraphrased by Heilbroner as

> the deliberate abandonment of economics as a science that reduces its conclusions or predictions from secure premises of behavior and technology, and its replacement by a conception of economics as a policy-oriented instrument whose major theoretical purpose is to discover what 'premises'—what behavioral forces, what technological constraints, what institutions—would be necessary to attain targets or goals. (p. 9)

Specifically, Lowe suggests that we begin policy analysis with the assumption of specified policy goals. One would then "work back" from the goals to identify preconditions to their achievement.

This focus need not draw economists into the debate regarding what policy goals "should" be. These are rightly defined by the body politic. The instrumental analysis of microbehavior is conceptually equivalent to the current approach to macroeconomic policy. Goals regarding inflation and unemployment are specified in the political arena and economists are consulted regarding preconditions to the achievement of these goals.

There is no ground for the charge that such an approach would draw economists far into the realm of the normative. In fact, instrumental economics would subject the economist to fewer such charges than is currently the case than when he argues that one policy alternative is more "economically efficient" than another.

In no way does the approach imply the abandonment of market economics or of price as a resource allocation mechanism. It does recognize that markets are instituted—that the outcome of free exchange through the price mechanism is a function of the institutional setting in which exchange takes place. Further, the existent institutional setting is the product of past public choices. There is never a policy vacuum. The implication is that there is merit in a conscious effort to shape the market to achieve desired resource allocation through the price mechanism. This effort will require multidisciplinary research involving economists, sociologists, psychologists, organization theorists, and legal specialists.

The development and adaption of a policy approach analogous to Lowe's is a major, long-term goal. A more immediate concern is to avoid the use of an economic efficiency criterion to compare policy alternatives.

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References

Boulding, Kenneth E. *Economics as a Science*: New York: McGraw-Hill Book Co., 1970.

Farrell, M. J. "The Measurement of Productive Efficiency." *J. Royal Statist. Soc.* 120, part 3, ser. A (1957), pp. 253–81.

Hall, Bruce F., and Phillip E. LeVeen. "Farm Size and Economic Efficiency." *Amer. J. Agr. Econ.* 60 (1978):589–600.

Heilbroner, R. L. "On The Possibility of Political Economics." *J. Econ. Issues*, no. 4 (1970), pp. 1–22.

Henderson, James M., and Richard E. Quandt. *Microeconomic Theory: A Mathematical Approach*. New York: McGraw-Hill Book Co., 1971.

Lowe, Adolph. "Toward a Science of Political Economics." *Economic Means and Social Ends*, ed. R. L. Heilbroner. Englewood Cliffs, N.J.: Prentice-Hall, 1969.

Mann, Thomas, and Arnold Paulsen. "Economic Impact of Restricting Feed Additives in Livestock and Poultry Production." *Amer. J. Agr. Econ.* 58(1976):47–53.

Mishan, E. J. *Cost Benefit Analysis*. New York: Praeger Publishers, 1976.

———. "Welfare Criteria: Resolution of a Paradox." *Econ. J.* 83(1973):747–67.

Schmid, A. Allan, and James D. Shaffer. "Marketing in Social Perspective." *Agricultural Market Analysis*, ed. Vernon L. Sorenson. East Lansing: Michigan State University Bus. Stud., 1964.

Appendix

The Analytics of External Diseconomies

Let (4) and (5) be production functions for livestock (L) and health (H). Each product relies on a common factor, V, which is fixed. The quantity of V devoted to the production of L and H are V_1 and V_2, respectively. The output of health is negatively affected by the production of livestock since feed additives used in its production are damaging to health. The partial derivatives are

$$L = l(V_1), \tag{4}$$

$$H = h[V_2,\, l(V_1)], \text{ and} \tag{5}$$

$\dfrac{\partial L}{\partial V_1}$ and $\dfrac{\partial H}{\partial V_2}$ are positive because the common factor contributes to the output of both. But the partial derivative $\dfrac{\partial H}{\partial V_1} = \dfrac{\partial h}{\partial l}\dfrac{\partial l}{\partial V_1}$ is negative.

The achievement of a Pareto-efficient allocation of resources requires that the marginal rate of product transformation (*MRPT*) equal the marginal rate of commodity substitution (*MRCS*). The *MRPT* is equal to the ratio dH/dL, and the *MRCS* is equal to the ratio of product prices in a competitive economy.

The ratio dH/dL can be formed with the total derivatives of (4) and (5), as in (6):

$$\frac{dH}{dL} = \frac{\dfrac{\partial h}{\partial V_2}\,dV_2 + \dfrac{\partial h \partial l}{\partial l \partial V_1}\,dV_1}{\dfrac{\partial l}{\partial V_1}\,dV_1}. \tag{6}$$

Since $V = V_1 + V_2$, $dV = dV_1 + dV_2$. Because $dV = 0$, $dV_1 = -dV_2$ and (6) can be rewritten as (7),

$$(7)\quad \frac{dH}{dL} = -\frac{\frac{\partial h}{\partial V_2} - \frac{\partial h \partial 1}{\partial 1 \partial V_1}}{\frac{\partial 1}{\partial V_1}} = -\frac{\frac{\partial V_2}{\partial h}}{\frac{\partial 1}{\partial V_1}} + \frac{\partial h}{\partial l}$$

$$= -\left[\frac{\frac{\partial h}{\partial V_2}}{\frac{\partial 1}{\partial V_1}} - \frac{\partial h}{\partial 1}\right] = MRPT.$$

In factor-use decisions, firms producing H and L consider only those factors they control. They produce at levels consistent with the ratio of product prices P_H and P_L for H and L. Their profit functions, as defined by (8) and (9), were r is the price of V:

$$(8)\quad \pi_H = P_H\, h(V_2) - rV_2, \text{ and}$$

$$(9)\quad \pi_L = P_L\, 1(V_1) - rV_1.$$

When each firm maximizes its profits, it will allocate resources as indicated in (10), to be consistent with the price ratio ($MRCS$):

$$(10)\quad P_H \frac{\partial h}{\partial V_2} = P_L \frac{\partial l}{\partial V_1}, -\frac{P_L}{P_H} = -\frac{\frac{\partial h}{\partial V_2}}{\frac{\partial l}{\partial V_1}} = MRCS.$$

But under these conditions, $MRCS$ (10) and $MRPT$ (7) are not equal. A Pareto-efficient solution will not be achieved. In (11), $MRPT$ is greater than $MRCS$ because the term $\frac{\partial h}{\partial l}$ is negative:

$$(11)\; MRCS = -\frac{P_L}{P_H} = -\frac{\frac{\partial h}{\partial V_2}}{\frac{\partial l}{\partial V_1}} <$$

$$-\left[\frac{\frac{\partial h}{\partial V_2}}{\frac{\partial l}{\partial V_1}} - \frac{\partial h}{\partial l}\right] = \frac{dH}{dL} = MRPT.$$

This represents a lower price of L relative to H than is consistent with the $MRPT$. Thus, the external diseconomy created by L on the production of H prevents the Pareto-efficient allocation of resources.

Because the external diseconomy is not internalized by livestock producers, they behave as if the $MRPT$ were equal to (10). If livestock producers were to internalize the cost of health risk, they would behave as if the $MRPT$ were (7), thereby producing less L and more H. The effective cost (and equilibrium price) of L relative to H would rise such that society is left with a Pareto-optimal allocation of resources.

Testing for Homogeneity and Habit Formation in a Flexible Demand Specification of U.S. Meat Consumption

Rulon Pope, Richard Green, and Jim Eales

Three common practical problems facing empirical analysts of demand relations are (*a*) the choice of a functional form for econometric estimation, (*b*) the decision whether to deflate price and income data and the related question, "Are demand equations homogenous of degree zero?" and (*c*) the representation of changing preferences.

The purpose of this paper is to test for homogeneity conditions and habit formation in a flexible demand specification. Box-Cox transformations are applied to four meat demand relations in order to allow for more flexible functional forms. Estimators of the demand parameters are obtained by using maximum likelihood techniques, and tests of homogeneity and habit formation are based on the likelihood ratio procedure. The analyses utilize annual U.S. data on beef, pork, poultry, and fish for the years 1950–75, and short-run effects are emphasized.

Many studies have focused on the demand for meat. Fuller and Ladd, Hayenga and Hacklander, and Tryfos and Tryphonopoulos used linear functional forms. The log form was used in Fox and Breimyer. More recently, Chang used the Box-Cox transformation in a dynamic model to investigate aggregate demand for meat in the United States. The linear and logarithmic forms are special cases of this more general functional form.

The above studies make no attempt to test restrictions implied by consumer theory. In contrast, recently, Christensen and Manser applied a translog utility system to meat demand and estimated demand parameters and tested theoretical restrictions. However, most econometric analyses of demand in agricultural economics do not use explicit utility function formulations but use arbitrary reduced forms (one recent exception is the work by Green, Hassan, and Johnson). This study adopts the latter approach because of increased ease of estimation and the ability to incorporate greater complexity in the dynamic formulation. These relations can be made locally (or, in some cases, globally) consistent with utility maximization by imposing restrictions on parameters (Court, Byron). However, homogeneity can be imposed globally as well as locally within a demand equation for many log-linear demand equations—it is noted here that Court assumed, but did not test for, homogeneity; however, Byron and others have tested for homogeneity (and usually rejected it) in more aggregated log-linear static systems. Because all demand specifications (whether a system or single equation) are amenable to homogeneity tests and because of general interest in the deflation issue, this study focuses on homogeneity restrictions.

Model

The transformation developed by Box and Cox and extended in Zarembka is of the functional form,

$$q_t^{(\lambda)} = (q_t^{\lambda} - 1)/\lambda, \tag{1}$$

where q_t is the tth observation of a variable and λ is some real valued parameter. For a single-equation demand specification, and applying the Box-Cox transformation, the static model becomes

$$\begin{aligned} q_{it}^{(\lambda)} = \beta_0 + \beta_1 P_{1t}^{(\lambda)} + \beta_2 P_{2t}^{(\lambda)} + \dots \\ + \beta_n P_{nt}^{(\lambda)} + \beta_{n+1} Y_t^{(\lambda)} + U_t, \\ i = 1, \dots, n \qquad t = 1, \dots, T \end{aligned} \tag{2}$$

where q_{it} is the per capita quantity demanded of the ith commodity in time period t, P_{jt} is the corresponding price of the jth commodity in time period t, Y_t is the per capita disposable income in period t, and U_t is a random error. Equation (2) reduces to the linear form when λ equals one. This can be seen easily by inspection of the equation. As λ approaches zero, the model approaches the double-log demand specification (see Box and Cox). Thus, the above functional form is a more general specification than the typical linear and double-log relations often employed by economists.[1]

The elasticity of q_{it} with respect to one of the explanatory variables, say P_{jt}, can be shown to be

$$\epsilon_{ij} = \beta_j (P_{jt}/q_{it})^{\lambda}. \tag{3}$$

For the linear case, $\lambda = 1$, the elasticity approaches

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[1] By relaxing the restrictive assumption that all the λ's are the same for each variable the semilog and log-inverse functional forms can be obtained. However, to reduce the computational burdens, only a single λ in each equation is considered.

one as the explanatory variable (P_{jt}) increases (Chang, p. 356). For the double-log case, the elasticities are constant with respect to changes in the explanatory variable. For example, if $\lambda < 0$ and the commodity is a superior good ($0 < \epsilon_{qY}$), then ϵ_{qY} decreases as (Y_t/q_t) increases.

Homogeneity

Theoretically derived demand functions are homogenous of degree zero in all prices and income if and only if

$$(4) \qquad \sum_{j=1}^{n} \epsilon_{ij} + \eta_{iY} = 0 \qquad i = 1, \ldots, n$$

where η_{iY} is the income elasticity associated with the ith commodity. For the Box-Cox functional form, this condition can be expressed as

$$(5) \qquad \sum_{j=1}^{n} \beta_j P_j^{\lambda} + \beta_{n+1} Y^{\lambda} = 0, \qquad i = 1, \ldots, n.$$

Thus, the Box-Cox demand function is globally homogenous; that is, equation (5) holds for all prices and income, if and only if the following conditions are satisfied:

$$(6) \qquad \lambda = 0 \text{ and } \sum_{j=1}^{n} \beta_j + \beta_{n+1} = 0.$$

The Box-Cox functional form is locally homogenous at specified prices and income, $\bar{P}_j$ and $\bar{Y}$, if and only if

$$(7) \qquad \sum_{j=1}^{n} \beta_j \bar{P}_j^{\lambda} + \beta_{n+1} \bar{Y}^{\lambda} = 0.$$

Dynamic Representations

The demand relation in equation (2) does not allow for persistence or inertia in consumption patterns. In order to account explicitly for habit formation, three habit-version demand specifications are considered. However, unlike previous research, we will adopt the Box-Cox transformation for its added generality. The first extension of the static model in (2) assumes that taste changes can be treated by adding a time trend to the original model, t. The second habit specification assumes that adjustment of actual consumption to desired consumption is achieved only partially during any given time period because of habit effects (Houthakker and Taylor). The model, with the Box-Cox transformations, differs from the static model in that transformed lagged consumption, $q_{it-1}^{(\lambda)}$ is added. The third habit-formation version is similar to the state adjustment model, in unrestricted reduced form, of Houthakker and Taylor—discussed, for example, in Phlips (pp. 164–69). In this model the quantity demanded of the ith commodity is assumed to be a function of the psychological stock of habits (S_t), prices, and income. By assuming that the time rate of change in the transformed stock of habits is equal to current transformed purchases minus losses due to depreciation, and substituting for the transformed unobservable psychological stock variable, $S_t^{(\lambda)}$, the model (see, e.g., Phlips, p. 168) differs from the static model by the inclusion of q_{it-1}, P_{jt-1}, and Y_{t-1}, which are lagged values of the quantities, prices, and income, respectively.

The elasticity formulas for the dynamic models are the same as given in (3). However, consider the effects of habits on elasticities. For example, the change in the elasticity with respect to a change in habits (represented by time) for the own-price elasticity in the time trend model is

$$(8) \qquad \frac{\partial \epsilon_{ii}}{\partial t} = -\lambda \epsilon_{q_i P_i} \beta_{n+2} t^{\lambda-1} q_i^{-\lambda},$$

where β_{n+2} is the coefficient of time. For normal goods, sign $\partial\epsilon_{ii}/\partial t$ = sign ($\beta_{n+2}\lambda$). Therefore, habits may increase, decrease, or leave unchanged the elasticities. For example, if $\lambda = 0$, then (8) is zero. Therefore, global homogeneity, (6), implies constant elasticity, and thus, necessarily, changing habits do not alter elasticities. When $\lambda = 1$, from (8), an increase in habits make demands more inelastic when β_{n+2} is positive. Similar results may be obtained for the partial and state adjustment models.

Estimation Methods

For estimating the above models, it is assumed that the error terms are normally and independently distributed with zero means and constant variances, σ^2, for a given λ. Box and Cox and Zarembka show that, given the above stochastic specification, the concentrated log likelihood for fixed λ is, except for a constant,

$$(9) \quad L_{\max}(\lambda) = -n/2 \ln \hat{\sigma}^2(\lambda) + (\lambda - 1) \sum_{i=1}^{n} \ln q_i,$$

where $\hat{\sigma}^2(\lambda)$ may be considered an estimate of σ^2 obtained by regressing $q_t^{(\lambda)}$ on transformed prices and income.[2]

There are two approaches one can take in estimation of (9). One can transform the data so that $q^{(\lambda)}$ is regressed on $P_j^{(\lambda)}$ and $Y^{(\lambda)}$, using ordinary least squares (OLS). Then a search is conducted by varying λ so as to maximize (9). Alternatively, the unconcentrated or concentrated likelihood function could be optimized by gradient methods that con-

[2] The likelihood function in (9) supposes that the optimal λ transforms q to a normally distributed random variable. However, as a number of authors have noted, strictly speaking, $q^{(\lambda)}$ cannot be normally distributed since it is not defined over the negative line (Poirier). Yet, Draper and Cox have shown that if $q^{(\lambda)}$ is reasonably symmetric, then the maximum likelihood estimator is fairly robust to nonnormality.

Table 1. Maximum Likelihood Estimates of the Parameters for the State Adjustment Demand Equation, 1950–75

State Adj. Model	Dep. Var. q_{it}	Explanatory Variables: Const.	Beef P	Pork P	Poultry P	Fish P	Income
1. Beef							
a. linear		−7.936	−0.693	0.035	0.019	0.165	0.354
		(0.39)[c]	(4.85)	(0.56)	(0.19)	(0.65)	(1.22)
b. maximum likelihood		−28.880	−0.647	0.034	0.003	0.220	0.423
		(0.22)	(4.70)	(0.62)	(0.03)	(0.98)	(1.56)
c. double log		−0.248	−0.789	0.064	0.027	0.064	0.253
		(0.22)	(4.41)	(0.65)	(0.22)	(0.17)	(0.66)
2. Pork							
a. linear		31.979	0.390	−0.578	0.136	−0.151	0.331
		(1.66)	(3.36)	(8.65)	(1.38)	(0.83)	(1.25)
b. maximum likelihood		6.257	0.350	−0.703	0.164	0.063	0.345
		(1.92)	(3.25)	(10.31)	(1.77)	(0.32)	(1.33)
c. double log		1.301	0.300	−0.858	0.198	0.334	0.362
		(1.58)	(2.39)	(9.68)	(1.83)	(1.30)	(1.12)
3. Poultry							
a. linear		3.398	0.321	0.190	−0.580	−0.115	0.452
		(0.30)	(2.66)	(2.90)	(5.84)	(0.56)	(1.54)
b. maximum likelihood		0.881	0.250	0.234	−0.599	0.248	0.579
		(2.59)	(3.28)	(4.48)	(9.77)	(1.50)	(2.93)
c. double log		1.046	0.271	0.229	−0.596	0.191	0.599
		(2.23)	(3.49)	(4.41)	(9.50)	(1.16)	(3.00)
4. Fish							
a. linear		5.300	0.412	0.147	−0.267	−0.081	1.098
		(2.23)	(2.87)	(1.53)	(1.66)	(0.32)	(3.27)
b. maximum likelihood		75035.4	0.424	0.068	−0.263	−0.314	0.600
		(2.16)	(3.53)	(1.36)	(2.09)	(2.01)	(2.52)
c. double log		2.660	0.303	0.159	−0.191	0.183	0.114
		(2.38)	(1.89)	(1.20)	(1.07)	(0.52)	(2.69)

[a] Value of the log likelihood function ignoring the constant.
[b] Adjusted R^2.
[c] Values in parentheses are t-ratios.
[d] The Durbin h-statistic cannot be computed because it entails taking the square root of a negative number.

verge on the value of the optimal λ. The former method is used here: the optimal value of λ is obtained by combining (9) and the OLS package such that the maximum likelihood estimate of λ is obtained to within three significant digits.

Because we are using a single-equation approach, some problems of simultaneity may arise. However, we are considering the demand relation for a "representative" consumer and expressing quantities and income in per capita terms. Thus, prices and income can be taken as exogenous and a single regression is reasonably appropriate. Furthermore, assuming, as Chang and others have, that shifts in the supply function of agricultural products vary much more than the demand for those products, a demand relation can be estimated without serious problems associated with simultaneity. Even when a demand-system approach is taken, strong assumptions on the supply side have to be made even though they are rarely explicitly mentioned or accounted for. However, in principle, endogeneity of prices could be tested (Sims). Yet, these approaches are cumbersome to apply and seldom used. If one assumes endogeneity incorrectly, then biased estimation procedures are used when OLS is "best." However, if prices are endogenous and OLS is applied, then the resulting estimates also are biased, and inconsistent as well. In small samples, it is unclear which approach should be taken. Here, the logical foundations of the representative consumer model imply that OLS is appropriate.

The Empirical Application

The static and dynamic relations presume that all prices enter demand functions. Pragmatically, it is impossible to accommodate theory precisely. Researchers often follow two general approaches: (*a*) include the prices of close substitutes and complements directly and use a price index, e.g., Consumer Price Index (CPI), for all other prices either as a deflator or as a separate independent variable (Stone); and (*b*) exclude all prices other than close complements and substitutes (Hassan and Johnson). The former approach is taken here and

	Explanatory Variables						Statistics		
q_{t-1}	Beef P_{-1}	Pork P_{-1}	Poultry P_{-1}	Fish P_{-1}	In-come$_{-1}$	λ	ln L^a	$\bar{R}^{2b}$	Durbin h
0.726	0.636	−0.098	0.068	−0.203	0.082	1	−12.300	0.987	N.A.[d]
(3.01)	(3.39)	(1.42)	(0.69)	(1.04)	(0.24)				
0.704	0.581	−0.103	0.080	−0.249	0.008	1.50	−11.793	0.987	N.A.
(2.97)	(3.19)	(1.60)	(0.85)	(1.43)	(0.02)				
0.655	0.666	−0.058	0.036	−0.114	0.253	0	−17.398	0.982	N.A.
(2.34)	(2.91)	(0.61)	(0.28)	(0.39)	(0.58)				
0.341	−0.117	0.322	0.051	0.130	−0.177	1	−9.382	0.953	N.A.
(1.32)	(1.05)	(1.74)	(0.54)	(0.69)	(0.51)				
0.335	−0.040	0.318	0.081	−0.156	−0.069	0.53	−7.317	0.960	N.A.
(1.62)	(0.41)	(1.97)	(0.91)	(0.82)	(0.21)				
0.361	0.059	0.338	0.110	−0.540	0.057	0	−10.786	0.947	N.A.
(1.76)	(0.52)	(1.93)	(1.05)	(2.19)	(0.14)				
0.580	−0.051	−0.122	0.413	−0.132	0.028	1	−12.206	0.996	1.526
(3.02)	(0.44)	(1.66)	(3.06)	(0.68)	(0.08)				
0.202	0.055	−0.066	0.187	−0.448	0.091	−0.16	−1.650	0.998	−4.63
(1.16)	(0.64)	(0.91)	(1.46)	(2.89)	(0.37)				
0.272	0.034	−0.085	0.237	−0.415	0.039	0	−2.079	0.998	−3.194
(1.57)	(0.39)	(1.22)	(1.89)	(2.68)	(0.15)				
0.191	−0.025	−0.122	0.341	−0.127	−1.104	1	−15.643	0.915	N.A.
(0.67)	(0.20)	(1.57)	(2.72)	(0.54)	(2.78)				
0.167	−0.011	0.057	0.310	0.200	−0.613	2.80	−12.504	0.942	N.A.
(0.64)	(0.10)	(0.92)	(3.23)	(1.34)	(2.11)				
0.170	0.015	−0.139	0.278	−0.329	−1.170	0	−18.794	0.884	N.A.
(0.57)	(0.10)	(1.44)	(1.95)	(1.03)	(2.41)				

was first used by Stone.[3] Income per capita is deflated by the CPI leaving the homogeneity test:[4]

$$\sum_{j=1}^{n} \epsilon_{ij} = 0 \qquad i = 1, \ldots, n.$$

The data used to obtain parameter estimates and to perform the above homogeneity tests are U.S. time-series observations on beef, pork, poultry, and fish 1950–75. Variables used are per capita food consumption in retail weight equivalents (1970 base), per capita income deflated by the CPI, and implicit price indices (1970 = 100) for the commodity groups (Food Consumption, Prices, and Expenditures).

Empirical Results

Parameter estimates for the three habit-formation models and for each of the four meat commodities were obtained. Based upon likelihood ratio tests, the static and partial adjustment models were rejected in favor of the state adjustment model. For the sake of brevity, only the latter results are given in table 1. (See Pope, Green, Eales for more details.) Results are recorded for the linear, double-log, and the functional form associated with the maximum likelihood value for λ. Though the estimates for the linear and double-log forms are maximum likelihood estimates (MLE's), given λ = 1 and λ = 0, respectively, only the estimates using the value of λ which maximizes (9) will be referred to as the MLE's.

With respect to goodness-of-fit measures, the adjusted R^2 values for all commodities and models indicate high degrees of fit. In most cases, the adjusted R^2 values are in the 80% to 90% range. The Durbin-Watson values do not suggest rejection of the null hypothesis of zero autocorrelation. In general, for the case of lagged dependent variables, the Durbin h-values are not suggestive of autocorrelation problems.

Income and Price Parameter Estimates

All direct own-price coefficients are negative for all commodities and functional forms with few exceptions. For the commodity, fish, in the double-log

[3] All of the results reported in this paper also were obtained using the second approach. Often the results differed substantially; yet the major conclusions of this paper are unaltered. Based upon theoretical and pragmatic reasons and the qualitative results, Stone's approach appeared superior.

[4] Implicitly, this assumes that the CPI is homogenous of degree one. The method used by Stone is attractive because it reduces collinearity as compared to the case where the CPI enters as a separate independent variable.

form and for the static and state adjustment models, and for all of the time-trend models, the own-price coefficient is positive. However, in all such cases, the coefficients are not significantly different from zero using any commonly used significance levels. In addition, all the own-price coefficients for the other commodities are significantly different from zero at the .01 level.

In general, the cross-price effects are positive, indicating gross substitution among commodities: the exceptions involve the commodity fish. The t-values associated with cross-price derivatives are usually smaller than those related to the own-direct-price coefficients. The estimated income effects are positive, indicating superior commodities. In most cases, these coefficients are significantly different from zero at the .05 level. Also, t-values are usually higher for the MLE estimates.

Homogeneity and Functional Form

The estimated λ's varied substantially across commodities and model specifications. They range in value from $\lambda = -.6$ to $\lambda = 2.8$. To determine if the linear and double-log forms differ significantly from the functional form obtained by maximizing the likelihood function, likelihood ratio tests are performed (Theil, pp. 396–97).

The likelihood ratio test results indicate that linear demand functions cannot be rejected for beef regardless of the model specification. However, the double-log form is rejected for both the partial and state adjustment models. For pork demand, the double-log specification is rejected in every case, while the linear formulation is rejected only for the state adjustment model. Almost the reverse is implied for poultry demands: the linear specification is rejected in every model, while the double-log rejected only for the time-trend model. The line and double-log specifications are rejected for fis demands in the partial and state adjustment model

These results provide strong support for the pos tion that more careful consideration needs to b given in the functional forms of demand relatio for meat. The traditional linear and double-lo forms are frequently inadequate.

Tests for global [refer to equation (6)] and loc [refer to equation (7)] homogeneity conditions the Box-Cox demand relations are provided in tab 2. Global homogeneity is rejected for all models an all commodities with the exception of poultry in th state adjustment model. Thus, the hypothesis of n money illusion is rejected in nearly every case. T put these results in perspective, others using th Rotterdam and log-linear demand systems als have rejected the property of homogeneity usin static aggregate systems (Barten, p. 46).

We also imposed local homogeneity conditions the means of prices and income in a manner simil to Byron and Court, who used a static log-linea demand system. Tests for local homogeneity cond tions are presented in table 2. These results a somewhat in contrast to those obtained for glob homogeneity. For example, local homogeneity not rejected in any model for pork; however, loc and global homogeneity is rejected for beef de mand. In general, the frequency of rejection of loc homogeneity is large but less than the frequency rejection of global homogeneity.

In summary, the results of table 2 indicate th homogeneity of meat demands is not a warrante maintained hypothesis. Therefore, our results su gest that a researcher should be cautious whe choosing between regression methodologies usin

Table 2. Results of Local and Global Homogeneity Tests Based on the Likelihood Rati Procedure

Commodity	Static	Time Trend	Partial Adjustment	State Adjustme
	Values of $-2 \ln \hat{\lambda}$			
1. Beef				
a. local	26.429*[a]	22.068*	14.001*	5.082*
b. global	29.475*	22.130*	29.367*	20.973*
2. Pork				
a. local	0.216	0.125	0.180	1.758
b. global	17.489*	16.677*	16.274*	6.953*
3. Poultry				
a. local	10.136*	2.542	9.909*	1.86
b. global	13.788*	15.434*	16.219*	2.022
4. Fish				
a. local	21.273*	8.264*	—[b]	0.749
b. global	21.553*	14.411*	15.874*	17.493*

Note: In every case the models are compared against the unrestricted maximum likelihood forms.

[a] The computed values are to be compared with the critical X^2 values of $X^2_{.05}$ (1) = 3.84 for the local homogeneity tests and $X^2_{.05}$ (2) 5.99 for the global homogeneity tests.

[b] No global maximum of the likelihood function could be obtained for reasonable values of λ.

either deflated or nondeflated data.[5] Because of the broad class of models considered and our choice of flexible functional forms, these results appear of general interest to researchers in demand analysis.

Price and Income Elasticities and Tastes

The price and income elasticities for the state adjustment model are presented in table 3. As can be observed from the entries in the table, generally the elasticities are relatively small (inelastic). Note that though homogeneity was usually rejected, the calculated elasticities, under the unrestricted, local, and global homogeneity restrictions, are similar. The values were computed at the means; however, their behavior generally will differ considerably over time, depending upon the value of λ computed by the maximum likelihood procedure. An exception is when $\lambda = 0$. In this case, elasticities are constant and invariant with respect to taste changes.

Clearly, the static model implies that tastes do not affect the elasticities. For the time-trend model, λ is positive for all commodities except poultry. Further, all of the estimated time coefficients (MLE) are positive except fish. Following (8), the passage of time implies that beef and pork demands are becoming more inelastic, while poultry and fish demands are becoming more elastic. Also, following calculations similar to (8), the results from the time-trend model indicate that beef and pork demands are becoming more income inelastic over time, while poultry and fish are becoming more income elastic.

For the state adjustment model, adapting Houthakker and Taylor's approach, it can be shown that the marginal effects of habits on demands (or elasticities) can be determined from the reduced-form model (see Philips, p. 168). In our case, it was not possible to apply the restrictions on reduced-form parameters as implied by the structure and perform nested hypotheses tests. Hence, these marginal effects cannot be estimated uniquely from the reduced form. However, given the state adjustment rationalization of (6), the estimated marginal effects of habits on the quantities demanded are positive for all commodities with the exception of fish.[6] This corresponds to the results derived from the time-trend model. Further, the marginal effects of habits on own-price elasticities is given by (8), where t is replaced by the stock of habits, S_t, and α is its associated coefficient in the structural state adjustment model. Hence, beef and pork demands become more price inelastic as the stock of habits increases.

Policy Implications and Conclusions

Theoretically, there is a direct linkage between demand relations which are homogenous and flexible. Our results indicate overwhelming evidence for rejection of homogeneity when a flexible functional form is used to model meat demand. These results, though at variance with the theory of individual choice are consistent with the findings of other researchers who tested homogeneity in demand systems with more restrictive functional forms and representations of changing tastes (see, e.g., Bar-

[5] If global homogeneity holds, then elasticity estimates should not be sensitive to the deflator used. However, if it does not hold, then parameter estimates will depend upon the deflator used, and regressions using nominal and deflated data will give different elasticity estimates. Hence, when homogeneity does not hold, a non-nested testing procedure must be used in order to find the "best" model. It should also be noted that local homogeneity is not a nested model of a globally homogenous model.

[6] The estimates for α, the habit coefficient, are approximately $\hat{\alpha} =$ 1.7, 0.4, 1.1, −1.4, respectively, for beef, pork, poultry, and fish.

Table 3. Price and Income Elasticities for the State Adjustment Model under Unrestricted, Global, and Local Homogeneity

Commodity	Beef *P*	Pork *P*	Poultry *P*	Fish *P*	Income
1. Beef					
a. unrestricted[a]	−0.690	0.042	0.003	0.262	0.448
b. global	−1.039	0.047	0.060	0.933	0.393
c. local	−0.679	0.058	−0.011	0.630	0.607
2. Pork					
a. unrestricted	0.316	−0.794	0.174	0.070	0.370
b. global	0.293	−0.860	0.201	0.365	0.366
c. local	0.322	−0.814	0.193	0.300	0.383
3. Poultry					
a. unrestricted	0.249	0.231	−0.601	0.245	0.580
b. global	0.296	0.235	−0.606	0.075	0.584
c. local	0.289	0.237	−0.609	0.084	0.572
4. Fish					
a. unrestricted	0.500	0.106	−0.295	−0.457	0.701
b. global	0.430	0.242	−0.323	−0.349	1.186
c. local	0.468	0.115	−0.268	−0.314	0.810

[a] The unrestricted model refers to the Box-Cox functional forms without the homogeneity conditions imposed.

ten). Therefore, the many varied ways of deflating data may lead to substantially different results.

Intimately linked to the homogeneity issue is that of functional form. The results reported here suggest that the linear and double-log functional forms are inappropriate as maintained hypotheses. The best functional form, however, is sensitive to the manner in which changing tastes are represented and to the commodity studied. Yet, for pork demands, the often used double-log form was rejected for every model considered. We conclude on the basis of likelihood ratio tests, that Box-Cox transformations may be a useful tool for analysts of meat demand because the double-log and linear functional forms were rejected in many of our cases.

Finally, the Box-Cox demand functions allow flexibility in the way habits affect demand elasticities. Suppose an increase in habits implies that the own-price demand elasticity increases (becomes more inelastic), then the double-log form would measure this phenomena incorrectly because elasticities do not change. Our results indicate that the impact of a future policy aimed at raising price may have a much lower effect on beef and pork demands (and larger impact on expenditures) than predicted from a double-log model (*ceteris paribus*).

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References

Barten, A. "The Systems of Consumer Demand Functions Approach: A Review." *Econometrica* 45 (1977):23–51.

Box, G. E. P., and D. R. Cox. "An Analysis of Transformations." *J. Royal Statist. Soc.* ser. B, 26 (1964):211–43.

Breimyer, H. F. *Demand and Prices for Meats.* Washington, D.C.: U.S. Department of Agriculture Tech. Bull. No. 1253, 1961.

Byron, R. "The Restricted Aitken Estimation of Sets of Demand Relations." *Econometrica* 38(1970):816–30.

Chang, H. "Functional Forms and the Demand for Meat in the U.S." *Rev. Econ. and Statist.* 59(1977):355–59.

Court, R. "Utility Maximization and the Demand for New Zealand Meats." *Econometrica* 35(1967):424–46.

Christensen, L., and M. Manser. "Estimating U.S. Consumer Preferences for Meat with a Flexible Utility Function." *J. Econometrics* 5(1977):37–53.

Draper, N., and D. Cox. "On Distributions and their Transformation to Normality." *J. Royal Statist. Soc* ser. B, 31(1969):472–76.

Durbin, J. "Testing for Serial Correlation in Least Squares Regression When Some of the Regressor Are Lagged Dependent Variables." *Econometrica* 38(1970):410–21.

Fox, K. A. "Structural Analysis and the Measurement of Demand for Farm Products." *Rev. Econ. and Statist* 36(1954):57–66.

Fuller, W. A., and G. W. Ladd. "A Dynamic Quarterl Model of the Beef and Pork Economy." *J. Farm Econ.* 43(1961):797–812.

Goldfeld, S., and R. Quandt. *Nonlinear Methods in Econometrics.* Amsterdam: North-Holland Publishing Co., 1972.

Green, R., Z. Hassan, and S. Johnson. "Maximum Likelihood Estimation of Linear Expenditure Systems with Serially Correlated Errors." *Europ. Econ Rev.* 11(1978):207–19.

Hassan, Z., and S. Johnson. "Consumer Demand for Major Foods in Canada." Ottawa: Agriculture Canada, Econ. Branch Pub. No. 76/2, 1976.

Hayenga, M., and D. Hacklander. "Monthly Supply Demand Relationship for Fed Cattle and Hogs." *Amer. J. Agr. Econ.* 52(1970):535–44.

Houthakker, H., and L. Taylor. *Consumer Demand in the United States 1929–1970.* Cambridge, Mass.: Harvard University Press, 1965.

Philips, L. *Applied Consumption Analysis.* Amsterdam North-Holland Publishing Co., 1974.

Poirier, D. "The Use of the Box-Cox Transformation in Limited Dependent Variable Models." *J. Amer Statist. Assoc.* 73(1978):284–87.

Pollak, R., and T. Wales. "Estimation of the Linear Expenditure System." *Econometrica* 37(1969):611–28

Pope, R., R. Green, and J. Eales. "Testing for Homogeneity and Habit Formation in a Flexible Demand Specification of U.S. Meat Consumption." Work Pap. No. 79-8, University of California, Davis, 1979

Sims, C. "Money, Income and Causality." *Amer. Econ Rev.* 62(1972):540–52.

Stone, R. "The Measurement of Consumers Expenditure and Behavior in the United Kingdom, 1920–38." New York: Cambridge University Press, 1954.

Theil, H. *Principles of Econometrics.* New York: John Wiley & Sons, 1971.

Tryfos, P., and N. Tryphonopoulos. "Consumer Demand for Meat in Canada." *Amer. J. Agr. Econ* 55(1973):647–52.

U.S. Department of Agriculture. *Food Consumption Prices, Expenditures.* Agr. Econ. Rep. No. 138, Supplement for 1975, Washington, D.C., 1977.

Zarembka, P. "Transformation of Variables in Econometrics." *Frontiers of Econometrics,* ed. P. Zarembka pp. 81–104. New York: Academic Press, 1974.

)pen-Loop Stochastic Control of Grain Sorghum rrigation Levels and Timing

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rop growth simulation models that consider the oil-plant-atmosphere continuum recently have be- ome an important research tool. Examples of rowth simulation models include those for corn Curry and Chen), cotton (Baker, Hesketh, Dun- an), alfalfa (Miles et al.), barley (Kallis and Toom- ıg), wheat (Trenbath), and grain sorghum (Arkin, 'anderlip, Ritchie). This article investigates the tility of the grain-sorghum-growth simulation ıodel of Arkin, Vanderlip, and Ritchie as an irriga- on management tool on the Texas High Plains ith economic criteria guiding decisions.

Most water-use studies (e.g., Swanson and Thax- on; Jensen and Musick; Shipley, Regier, Wehrly) mphasize the need for coordinating irrigation with vater requirements of the plant during critical tages of plant development. Yield response attrib- ted to a specific irrigation depends upon several ictors, including: (*a*) amount of soil moisture vailable at the time of irrigation; (*b*) stage of the lant development; and (*c*) interaction effect from revious or subsequent irrigations, or both, which educe or eliminate moisture stress conditions. Iormally, three or four irrigations are applied to rain sorghum in the Texas High Plains to meet vater use requirements during the growing season. pplications may vary from only one preplant to as ıany as six postplant waterings (Shipley and Re- ier).

Increasing concern for the declining groundwater upply and energy costs along with potential energy urtailments in the region emphasize the impor- ance of improved irrigation planning and manage- ıent. Potential fuel curtailments magnify the already existing degree of risk and uncertainty of farming in areas with low and unstable rainfall. This uncertainty results in production practices that depart from the optimal deterministic input-output combinations, even for risk-averse producers. Previous estimates of economically optimal irrigation water application rates, and estimates of the impact of rising energy costs were primarily based on the assumption that the producer knew in advance the state of the different future environments that would surround him (Casey, Jones and Lacewell; Lacewell; Condra and Lacewell). Climatic, institutional, and economic conditions throughout the production year were considered as known at the beginning of the year.

To overcome these limitations, the computerized grain sorghum growth model was modified to consider stochastic situations in weather and/or institutional factors, and allow irrigation timing and quantity decisions to be based on an expected profit-maximizing criterion. The model was used to address two basic issues: (*a*) irrigation strategies that maximize net returns per acre of sorghum; and (*b*) the expected effects that irrigation fuel curtailments would have on the distribution of optimum amounts of irrigation water among the remaining irrigation periods and associated impact on grain sorghum yield and net returns.

The analysis of optimum irrigation strategies and effect of fuel curtailment were addressed under weather scenarios of (*a*) perfect knowledge, and (*b*) stochastic events. Throughout this analysis it is implicitly assumed that sophisticated irrigation technologies exist. This technology is loosely defined as that which would allow the application of up to eight postplant irrigations in a timely sense and would permit application of specific as well as small amounts of water.

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Optimal Allocation in a Dynamic and Stochastic Environment

The problem of optimal allocation of irrigation water in a production process over one growing season can be represented by the following set of equations:

$$(1) \quad J(\mathbf{X}_t, \mathbf{U}_t, t) = \sum_{t=0}^{T-1} I(\mathbf{X}_t, \mathbf{U}_t, t) + F(\mathbf{X}_T),$$

where J is a function made up of the summation of the net returns from a T-stage system operating under a deterministic environment; the intermediate function $I(. . .)$ represents the values for each period up to $T-1$; $F(.)$ is the gross revenue or terminal state function. The vector of state variables, $\mathbf{X}$, represents the values obtained by the system at each period t, while $\mathbf{U}_t$ is the control vector.

Maximization of the objective function (1) is subject to

$$(2) \qquad X_{t+1} = f_t(X_t, \mathbf{U}_t, t),$$

$$(3) \qquad g(X_t, \mathbf{U}_t) \leq b_t,$$

where the planting date, (t_0), the state of the system at planting time, (X_0), and the date at which the physiological maturity of the plant is reached, (T) are characteristics determined within the system. Equation (2) represents the dynamic behavior of a deterministic system indicating that the change in the level of the state variable at any instant is a function of its present state, the decision taken, and the time period; equation (3) represents the constraints imposed on the control variables.

Similar to the deterministic case, the problem of optimal allocation of irrigation water in a production process when stochastic conditions exist can be modeled as a control problem. In those cases where uncertainties can be adequately described as stochastic processes, the state of the system at time t is presumed to evolve according to

$$(4) \qquad \mathbf{X}_{t+1} = f(\mathbf{X}_t, \mathbf{U}_t, \mathbf{V}_t, t), \quad t = 0, 1, \ldots, T-1$$

with $\mathbf{X}_t$ and $\mathbf{U}_t$ being vectors of the state and control variables at time t, and $\mathbf{V}_t$ being the vector of stochastic factors. In this case, the choice of controls, which is a multistage decision process, constitutes a stochastic problem, and the way of choosing $\mathbf{U}_t$ determines the class of control policies to be applied. These classes of stochastic control policies are defined according to the information on past and anticipated future observations available to the controller. Knowledge about the probabilities of future observations allows the controller to anticipate statistically the information to be obtained from subsequent observations, with the anticipated information used in deciding the most desirable present action.

According to the amount of information used, four classes of stochastic control policies—as defined by Bar-Shalom and Tse—can be distinguished: open-loop (OL), open-loop feedback (F), m-measurement feedback (mF), and closed-loop (CL). It should be noted that F, mF, and CL have the same information about the past. The only difference among them resides in the anticipation of future knowledge. Of these four policies, the optimal stochastic control belongs, in general, to the closed-loop class (Bar-Shalom and Tse; Intriligator; Rausser).

Inherent analytical difficulties in deriving the closed-loop control rule suggest other policy classes should be used as an approximation. Analytical hardships can be reduced by decreasing the amount of information anticipated by the decision maker. Because of the complexity involved in modeling and analytical solution of the stochastic closed-loop policy, the stochastic open-loop feedback control was considered as an alternative for this study. Although the limitation of finding an analytical solution could not be overcome for this control, the possibility of being modeled so as to obtain a numerical solution leaves it as a viable alternative.

Model Description and Procedure

The basis of this study is the computerized grain sorghum growth model developed by Arkin, Vanderlip, and Ritchie. The core model is a system representation of the soil-plant-atmosphere continuum. Because a detailed description of the model is available, this discussion is limited to a brief account of the relevant components.

The model is based on a set of physiological efficiency functions that reflect effects of all (nonoptimal as well as optimal) weather and irrigation conditions. At the heart of the model is a net photosynthesis efficiency function. Potential net photosynthesis (Po) is defined as the net CO_2 fixed on a ground area basis for nonlimiting water and temperature conditions. When limiting factors exist, the potential value is reduced by some fraction that reflects the stress imposed on the plant due to the presence of a nonoptimum environment; i.e., extremely high or low temperatures and/or lack of water availability. Whenever water or temperature conditions are limiting, net photosynthesis is considered given by

$$(5) \qquad P = (Po\, \xi_1\, \xi_2) - N,$$

where P is the net photosynthetic rate of the crop; Po remains as defined before; ξ_1 and ξ_2 are efficiency parameters corresponding to temperature and soil water; and N is the value of the nighttime respiration losses. The parameters ξ_1 and ξ_2 are dimensionless fractions whose values vary between 0 and 1, depending on stress. Expression (5) was based on the assumption that limiting variables in the environment proportionately reduce the photosynthetic rate regardless of the value of the other limiting variables. Each efficiency parameter represents a particular environmental constraint on the photosynthetic rate.

The temperature efficiency parameter, ξ_1, forces a complete inactivity in photosynthesis for values below 5°.centigrade (C) and above 45°.C. An optimal range is considered to be between 25° C and 40° C. Limitation in soil moisture is reflected by the coefficient ξ_2. Reductions in net photosynthesis

re considered to be proportional to the reduction ı plant evaporation resulting from a limited supply f water. As reported by the study, plant evapora- on is not affected until a threshold of extractable oil water is reached. When approximately 80% of ıe extractable soil water is depleted by evapo- anspiration, the value of the soil water parameter, ,, becomes less than one indicating net photosyn- ıesis is affected. This relationship is somewhat peculative, and net photosynthesis may be af- cted to a larger degree if it is limited more by plant ater status than it is by evapotranspiration (Arkin, anderlip, and Ritchie).

Model application requires specification of the umber of leaves produced by the plant, the maxi- ıum area capable of being developed by each leaf, lant population, row spacing, planting date, titude, extractable soil water content on planting ate, and extractable soil water capacity. The plant sed in the simulation model was considered to ave seventeen leaves—each one with a maximum rea of 0.88, 2.30, 7.60, 12.30, 22.80, 42.50, 69.50, 13.00, 170.80, 248.80, 287.00, 357.50, 336.50, 40.80, 272.30, 209.30, and 116.00 centimeters cm.), respectively (Arkin). A row spacing of 68.60 m. was used in equipopulated plantings of grain orghum together with a population level of 148,200 lants per hectare (ha.). Latitude is also required ecause the sun's altitude and azimuth determine ıading of leaves. The soil water content was con- dered to have a maximum capacity of 15 cm. xtractable soil water content on planting date was onsidered to be 10 cm. to reflect a preplant irriga- on of approximately 4 inches.

Although the grain sorghum model simulates aily conditions, determination of optimum irriga- on levels on a daily basis would be computation- lly prohibitive. Consequently irrigation was con- dered in only eight periods, which were the twen- eth day after plant emergence and every tenth day ıereafter until harvest.

he Feedback Model

he approach to simulating the performance of pen-loop stochastic control for the problem at and is to first solve a deterministic optimization roblem for all eight irrigation periods within a crop ear. The deterministic model is formed by replac- g all stochastic variables with their expected val- es which are conditioned on weather prior to the rst irrigation period. Then the irrigation level ob- ined for the first period is applied, with the solu- on for all other periods ignored. Actual weather etween the first and second irrigation periods is ıen used to update the system and also to revise ıe conditional expectations for the remaining fu- ıre periods. With the revised conditional expecta- ons, a deterministic optimization model for the econd through the eighth period is solved, with nly the solution for the second period used in the mulation. This updating and repeated solution process continues in the above manner until a solution for the eighth period (i.e., a solution to a one-period optimization model) is applied to the system. Finally, actual weather throughout the growing season is simulated with the irrigation levels for the eight periods to obtain actual crop yield and net returns.

Generation of Conditional Expectations

Generation of conditional expectations was based on research by Rockwell, who concluded that the presence of rainfall could be treated as a binomial random variate, with the amount of rainfall determined by an empirical distribution modeled for each month. The distribution obtained was assumed to satisfy

$$(6) \qquad X = (e^{F(X)n/\hat{b}} - 1)/\hat{a},$$

where $\hat{a}$ and $\hat{b}$ are the parameters estimated by the nonlinear regression

$$(7) \qquad RANK = b \ln[a(X) + 1],$$

where $RANK$ is the number of observations for each level of rainfall, X is the amount of rainfall observed, and n is the maximum value for $RANK$. If the occurrence of rain was determined, the amount in which it happened was estimated by equation (6).

The probability distribution for solar radiation was based on a three-way empirical frequency table conditioned by both precipitation and maximum temperature for the day. A three-way empirical frequency table was also built for maximum temperature (*TEMPMX*). The value of *TEMPMX* was conditioned on that day's amount of rainfall and the maximum temperature during the previous day. Finally, once maximum temperature was determined, minimal temperature was estimated by means of a transformation under the assumption that these two variables were approximately bivariate normal distributed.

Based on these conditional expected values for all future periods, the amount of irrigation water to be applied during specified periods of the production process to maximize expected per acre profit were computed. A quasi-Newton method was used to numerically search for the profit-maximizing control vector.

Results

Analysis of optimum irrigation strategies and effect of fuel curtailment were addressed under scenarios of (*a*) perfect knowledge case (known weather pattern) for which the open-loop feedback control yields the optimal closed-loop solution; and (*b*) the stochastic case (random climatic values as well as uncertain energy curtailments) for which the open-loop feedback control is used as an approximation

to the optimal closed-loop control. The analysis was extended over thirty simulated sets of weather patterns, based on daily weather records obtained from the Texas A&M Experiment Station near Lubbock for the 1945–77 period.

For the analysis, the price of natural gas was assumed to be $2.50 per one thousand feet (mcf). Well characteristics were assumed to be a lift of 250 feet and a yield of 800 gallons per minute at 30 pounds pressure per square inch. Other costs of production were taken from enterprise budgets applicable to the region (Extension Economists-Management). The price of grain sorghum was set at the 1978 target price of $4.07 per hundredweight.

Perfectly Known Environments

For this case, all environments (economic, climatic, and institutional) are assumed to be known at the beginning of the simulation process. As contrasted to the stochastic case, values of the control variable can be, and in fact are, established in the first period. This is because in all subsequent periods, the expected values are identical to the realized or actual values, hence, no adjustments are needed during the growing season. These results provide the optimal or profit maximizing irrigation strategies in the absence of weather risk and, hence, a benchmark for determining the performance of the stochastic open-loop control policies.

Table 1 summarizes results obtained for thirty different weather patterns. Amounts of water used in the eight irrigation periods within a specific year differed as well as the levels applied in each period across the years. These results indicated that frequent irrigations with small application rates produce, *ceteris paribus*, higher net returns than a strategy of applying the same total amount of irriga tion water on a less frequent basis. Of course, practical constraint to several small irrigation appli cations is the limited number of wells on a typica farm. Irrigation application numbers and rates ar sensitive to acres irrigated and the type of distribu tion system.

The total amount of growing season water to b applied could be expected to be in the range of 10. to 11.5 inches 95% of the time. This is irrigatio water applied to the plant and does not includ distribution system or environmental losses asso ciated with applications. In addition, preplant irri gation water is not included. It is assumed that soi moisture is available at planting. Thus, to obtai total irrigation needed, the preplant applicatio (about 4 inches net to the plant), would have to b added. An average amount of 1.1 to 1.4 inche would be required in all periods but the first, whic needs an average amount of 2.6 inches.

Of particular importance are the maximum an minimum values of irrigation water required at eac period and especially the minimum values. Thes quantities of irrigation water, over the thirty year of weather patterns, indicate that a profit maximizing producer should irrigate in at least fou periods in all years; i.e., the first, sixth, seventh and eighth. In the first period, a minimum amoun of about 1.5 inches can be expected in any year.

Under the assumed economic, institutional, an climatic conditions, average yield and net return that could be expected are about 90 cwt. and $110 respectively, as shown in table 2. Values for thes two variables would be expected to fall in the rang of approximately 87–91 cwt. and $102–$116, 95% o the time. This provides an indication of the op timum allocation of water under perfect knowledg and a good indication of the true optimum, aver aged over time.

Table 1. Optimal Post-Plant Irrigations to Maximize Net Returns per Acre of Grain Sorghun with Deterministic Weather Patterns: Texas High Plains

Days after Plant Emergence	Post Plant Irrigation Period	Application Rate Characteristics[a] Mean[b]	Standard Deviation	Minimum Value	Maximum Value	Coefficient of Variatior
		(Inches)				(%)
20	1	2.62	0.45	1.49	3.23	17.09
30	2	1.10	0.38	0.00	1.59	34.15
40	3	1.34	0.57	0.00	2.21	42.63
50	4	1.15	0.57	0.00	2.03	49.63
60	5	1.19	0.55	0.00	1.97	46.52
70	6	1.35	0.38	0.45	1.91	28.57
80	7	1.25	0.38	0.16	1.76	30.66
90	8	1.12	0.45	0.22	1.74	39.89

Note: Based on a price of grain sorghum of $4.07/cwt. and natural gas, $2.50/mcf.
[a] Based on 30 simulated replicates.
[b] Irrigation water applied to the plant.

Table 2. Per Acre Net Returns, Yield, and Irrigation Level for Deterministic and Stochastic Weather Patterns: Texas High Plains

	Perfectly Known			Stochastic		
Item	Net Return	Yield	Water Used[a]	Net Return	Yield	Water Used[a]
	($)	(cwt.)	(in.)	($)	(cwt.)	(in.)
Mean	109.54	89.89	11.11	99.36	89.94	13.80
Standard deviation	17.99	5.02	1.18	17.81	5.06	0.80
Minimum value	75.20	79.38	8.98	61.67	79.38	11.21
Maximum value	146.82	99.28	13.58	132.43	99.28	15.05
Coefficient variation	16.42	5.58	10.62	17.92	5.63	5.79

Note: Based on thirty simulated replicates and a price of grain sorghum of $4.07/cwt., and price of natural gas of $2.50/mcf.
[a] Irrigation water used applies to the plant excluding a pre-plant irrigation.

Stochastic Environments

The complete knowledge assumption was relaxed to reflect two cases: (*a*) stochastic weather environments, and (*b*) stochastic weather with energy curtailments. In the first case, results obtained from using the open-loop feedback control are compared to the results obtained from the perfect knowledge case to provide implications of the effect of uncertainty on overall performance of the model.

Results of the open-loop stochastic control strategy without energy curtailments are summarized in table 3 for thirty simulations. Compared to the perfect knowledge case (table 1), the mean values for irrigation water applied were always slightly higher for the stochastic case. For periods 3 through 8, the increase in irrigation level is from .3 to .5 of an inch or a 20% to 30% increase. For the stochastic weather case, some irrigation water is always applied in every period contrary to the perfect knowledge case.

Thus, general interpretations are that with the open-loop feedback control, results obtained for yields did not differ from those obtained in the perfect knowledge case. However, differences between the two cases were found in the optimal amount of water to be applied and therefore in cost and net returns. In the stochastic case, the use of irrigation water had a mean value of 13.80 inches, approximately 25% more than in the case of complete knowledge. Because of the higher amount of water used per acre, net returns were diminished by 10% (from $110 in the deterministic case to $99 in the stochastic case). This could be considered to be the cost of not possessing complete information.

Stochastic Energy Curtailments

To evaluate the effects that potential energy curtailments may have on producer's net revenues, yields, and water used, fuel curtailments were incorporated by blocking any irrigation for a predetermined period or periods. For this analysis, stochastic weather patterns also were used. Different sets of shocks (curtailments) were introduced to the system as random events. Three arbitrarily defined time spans of curtailments were examined (ten, twenty, and thirty days in duration). In all cases analyzed, it was assumed that the producer

Table 3. Optimal Post-Plant Irrigations to Maximize Net Returns per Acre of Grain Sorghum with Stochastic Weather Patterns: Texas High Plains

Days after Plant Emergence	Post-Plant Irrigation Period	Application Rate Characteristics[a]				
		Mean[b]	Standard Deviation	Minimum Value	Maximum Value	Coefficient of Variation
		(Inches)				(%)
20	1	2.63	0.42	1.49	3.12	16.19
30	2	1.25	0.23	0.62	1.54	18.62
40	3	1.66	0.30	0.90	2.22	17.90
50	4	1.63	0.21	1.15	2.05	12.58
60	5	1.69	0.16	1.36	2.02	9.68
70	6	1.68	0.19	1.13	1.94	11.50
80	7	1.67	0.15	1.37	1.98	8.93
90	8	1.60	0.14	1.25	1.86	8.67

Note: Based on a price of grain sorghum of $4.07/cwt. and price of natural gas of $2.50/mcf.
[a] Based on thirty simulated replicates.
[b] Irrigation water applied to the plant excluding a pre-plant irrigation.

Table 4. Estimated Effect of Twenty-Day Curtailments on Per Acre Yield, Net Returns, and Irrigation Level for Grain Sorghum: Texas High Plains

	Days after Emergence When Curtailment Occurred								
	20–40			40–60			60–80		
Item	Net Return	Yield	Water Used[a]	Net Return	Yield	Water Used[a]	Net Return	Yield	Water Used[a]
	($)	(cwt.)	(in.)	($)	(cwt.)	(in.)	($)	(cwt.)	(in.)
Mean	94.64	86.45	11.83	71.45	80.01	11.97	83.37	83.56	12.12
Standard deviation	19.47	5.45	0.96	29.91	7.91	0.94	25.10	6.70	0.99
Minimum value	56.12	75.66	8.18	11.60	64.21	10.31	37.75	68.34	9.74
Maximum value	129.84	96.27	13.42	119.22	92.43	13.36	135.28	96.21	14.06
Coefficient of variation	20.57	6.30	8.11	41.86	9.89	7.85	30.11	8.02	8.17

Note: Based on thirty simulated replicates, a price of grain sorghum of $4.07/cwt., and price of natural gas of $2.50/mcf.
[a] Irrigation water applied to the plant excluding a pre-plant irrigation.

could not foresee the future existence of energy restrictions, so optimal allocations of irrigation water were sought assuming complete availability of water. For those periods where curtailments had been defined to take place, the initial decision to irrigate was overriden, forcing the model to consider rain as the only source of water. In the present context, curtailments should be considered as the number of days by which planned irrigation is delayed.

For ten-day curtailments, there were no changes in yields or total amounts of irrigation water as compared to the stochastic situation presented in table 2. Only the distribution of the water used per period changed. The analysis suggests that to obtain maximum net returns, the best action to follow after a ten-day curtailment is to supply the plants with the moisture required so that no major stress is imposed in growth. This alternative is subject to the condition that optimal amounts of water had been supplied in the previous periods, and that water will be delivered immediately after the curtailment has ceased.

Net revenues for the three different twenty-day curtailments analyzed reflected a decline in their mean value as shown in table 4. Net returns are more severely affected when curtailment takes place during the period of forty to sixty days after emergence. During this period, the head is developing and sunlight interception approaches its maximum. In this period, growth and nutrient uptake occur rapidly, necessitating adequate supplies of nutrients and water.

In the case of curtailments during the forty to sixty days after emergence period, net returns decreased 28% with respect to the no-curtailment case. What is even more significant, though, is the increase in the coefficient of variation: from approximately 18% (for the no-curtailment stochastic case of table 2) to 42%. The minimum value of net returns dropped from $62 to $12, while maximum net returns declined from $132 to $119. The same trend was observed for yields; for a mean of 90 cwt. without curtailment to 80 cwt. (approximately 11% less).

Similar consequences were observed for curtailments during the half-bloom and soft-dough stage of the plant (approximately sixty through eighty days after emergence). In these periods, grain formation begins. Any reduction in plant size and leaf area occurring in this period cannot be completely overcome in later periods. Net returns for curtailments during these stages were observed to decrease about 16% (from $99 for the no-curtailment case to $83), and their variation increased from 18% to 30%. Yields for these periods also experienced a decline of 7%.

Impacts similar to the twenty-day curtailment are obtained for the thirty-day case except the effects are greater (table 5). Periods where curtailment was imposed were twenty to fifty and forty to seventy days after plant emergence. Of the two instances, the latter reflected more severe impacts. During these periods, and different to the cases analyzed before, negative net returns are present in the solutions obtained for some years.

Average net returns and yields for the twenty to fifty and forty to seventy day after plant emergence curtailment are $67 and $50 and 77 cwt. and 73 cwt., respectively, representing a decrease of almost 50% and 19% with respect to the noncurtailment case.

In summary, the primary effects of irrigation curtailments are to reduce net revenues and increase their relative spectrum of fluctuation. The amounts in which they are reduced is dependent upon the stage of growth of the plant and the time span of the curtailment.

These estimates should be taken as being conservative. To obtain them, the model—using the assumption of immediate delivery of water—

Table 5. Estimated Effect of Thirty-Day Curtailments on per Acre Yield, Net Returns, and Irrigation Level for Grain Sorghum: Texas High Plains

	Days after Emergence When Curtailments Occurred					
	20–50			40–70		
Item	Net Return	Yield	Water Used[a]	Net Return	Yield	Water Used[a]
	($)	(cwt.)	(in.)	($)	(cwt.)	(in.)
Mean	66.97	77.22	10.59	50.16	72.92	11.02
Standard deviation	35.31	9.60	1.03	33.91	9.08	0.90
Minimum value	−10.16	56.18	7.81	−11.73	56.52	8.77
Maximum value	119.85	92.54	12.04	117.36	91.60	12.61
Coefficient of variation	52.73	12.43	9.73	67.60	12.45	8.71

Note: Based on thirty simulated replicates, a price of grain sorghum of $4.07/cwt., and price of natural gas of $2.50/mcf.
[a] Irrigation water applied to the plant excluding a pre-plant irrigation.

optimizes the amount of irrigation water needed at the time that it is required. However, with the given state of the arts, this may not be the case. The twenty- or thirty-day curtailment period might be applicable to much shorter actual fuel curtailment periods. Producers lose not only the time of fuel curtailments but, also, they must cover many acres with a limited number of wells. As a result, a ten-day fuel curtailment could easily result in a twenty- to thirty-day delayed irrigation on some fields.

Concluding Remarks

As a last word of caution it should be pointed out that this study could not cover and evaluate all possible alternatives that might arise; therefore, certain needed constraints and limitations were adopted: to determine the optimal time trajectory for the control variable, the assumption of profit maximization was made. However, this goal may not reflect the objective of each producer. Other goals could be alternatively specified, i.e., secure some minimum net return or produce to the extent that minimum variations in net returns are obtained. Which specification is chosen may alter the value of the control variable.

The process of numerical search to maximize the value of the objective functional by no means assures a global rather than a local maximum. Though parametric analyses were made to assure that no other higher values exist at least in the vicinity, the possibility of finding higher values is still open. The main reason for this resides in the highly nonlinear shape of the objective functional.

Optimization of net revenue was made under the assumption that water was available at the time needed and in the amounts required. However, as mentioned before, a limited number of wells imposes the restriction of a limited amount of water that can be obtained in a given period of time while typically there are approximately 80 acres to be irrigated from each well.

Optimization was made with respect to the use of water and assumes the plant is affected exclusively by the climate. Inclusion of fertilizer and insect interaction would help on the predictive ability of the model.

Lastly, grain sorghum is considered to be the only crop under production. Most farmers grow more than one irrigated crop; consequently, in cases where water is a limiting factor, other crops would compete for the supply of the resource determining a possible different allocation for the control variable.

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References

Arkin, G. F. Personal communications. Temple, Texas, 1977.

Arkin, G. F., R. L. Vanderlip, and J. T. Ritchie. "A Dynamic Grain Sorghum Growth Model." *Transactions of the Amer. Soc. Agr. Eng.* 19(1976):622–26, 630

Baker, D. N., J. D. Hesketh, and W. G. Duncan. "Simulation of Growth and Yield in Cotton: I. Gross Photosynthesis, Respiration and Growth." *Crop Sciences* 12(1972):431–35.

Bar-Shalom, Y., and E. Tse. "Concepts and Methods in Stochastic Control." *Control and Dynamic Systems: Advances in Theory and Applications,* ed. C. T. Leondes, vol. 12, pp. 99–172. New York: Academic Press, 1976.

Casey, J. E., L. L. Jones, and R. D. Lacewell. *Impact of Limited Fuel Supplies on Agricultural Output and Net Returns: Southern High Plains of Texas.* Texas Agr. Exp. Sta. MP-1175, Jan. 1975.

Condra, G. D., and R. D. Lacewell. *Effects of Alternative Product and Input Prices on Demand for Irrigation Water: Texas High Plains.* Texas Agr. Exp. Sta. TA-11981, July 1975.

Curry, R. Bruce, and L. H. Chen. "Dynamic Simulation

of Plant Growth—Part II. Incorporation of Actual Daily Weather and Partitioning of Net Photosynthate." *Transactions of the Amer. Soc. Agr. Eng.* 14(1971):1170–74.

Extension Economists-Management. "Texas Crop Budgets." Texas Agr. Extens. Ser. MP-1027, 1978.

Intriligator, M. D. *Mathematical Optimization and Economic Theory*. Englewood Cliffs, N.J.: Prentice-Hall, 1971.

Jensen, M. E., and J. T. Musick. *Irrigating Grain Sorghum*. Washington, D.C.: U.S. Department of Agriculture, Leaflet No. 511, June 1962.

Kallis, A., and H. Tomming. "Estimation of the Influence of Leaf Photosynthetic Parameters, Specific Leaf Weight and Growth Functions on Yield." *Photosynthetica* 8(1974):91–103.

Lacewell, R. D. *Some Effects of Alternative Energy Issues on Stability in the Great Plains*. Texas Agr. Exp. Sta. TA-11884, May 1975.

Miles, G. E., R. J. Bula, D. A. Holt, M. M. Shreiber, and R. M. Peart. "Simulation of Alfalfa Growth." Paper presented at a meeting of the Amer. Soc. Agr. Eng., 17–20 June 1973, Lexington, Ky., Pap. No. 73-4547, *ASAE*, 1973.

Rausser, G. C. "Active Learning, Control Theory, and Agricultural Policy." *Amer. J. Agr. Econ.* 60(1978):476–90.

Rockwell, D. A. "Nonlinear Estimation," Mimeographed. Washington, D.C.: USDA Statist. Rep. Serv., Res. and Develop. Branch, Res. Div., 1975.

Shipley, J., and C. Regier. *Water Response in the Production of Irrigated Grain Sorghum, High Plains of Texas*. Texas Agr. Exp. Sta. MP-1202, June 1975.

Shipley, J., C. Regier, and J. S. Wehrly. *Soil Moisture Depletion Levels as a Basis for Timing Irrigations on Grain Sorghum*. Texas Agr. Exp. Sta. Consolidated PR-2546-2555, June 1968.

Swanson, N. P., and E. L. Thaxton, Jr. *Requirements for Grain Sorghum Irrigation on the High Plains*. Texas Agr. Exp. Sta. Bull. 846, Jan. 1957.

Trenbath, B. R. "Application of a Growth Model to Problems of the Productivity and Stability of Mixed Stands." *Proceedings*, 12th International Grasslands Congress, Moscow, USSR, 11–12 June 1974.

Empirical Estimates of Interregional Feedback in Input-Output Models and Model Approximations

Dean F. Schreiner and James C. Chang

.egional input-output models have been used idely to analyze impacts of exogenous changes to region's economy or the effects of economic rowth on a region. In addition, regional input-utput models have had application in energy and nvironmental planning. Richardson's book gives a seful summary of input-output models, their appli-ation and their limitations.

What has not been covered adequately in the terature is the importance of "interregional feed-ack" when using a regional rather than an interre-ional input-output model. Interregional feedback defined as the secondary trade effects in the out-ut of one region from an increase in that same egion's final demand. An increase in output in re-ion *m* will lead to an increase in *m*'s imports from ome or all of the other *r*-1 regions in the system, nd the induced expansion in those regions' exports ill have a multiplier effect on levels of output. These higher output levels will be associated with sing imports, some of which will take the form, ither directly or indirectly, of expanded exports om region *m* (Richardson, p. 78).

How important are interregional feedbacks? Vhat can be done about estimating feedbacks short f constructing a complete interregional model ithin a relatively closed system? This study esti-nates the interregional feedback effects for the tate of Oklahoma utilizing the data sets developed y the Harvard Economics Research Project HERP) and contained in the Multi-Regional nput-Output (MRIO) analysis studies (Polenske et l. 1972b, 1974; Rogers 1972, 1974; Scheppach 972). Second, an approximation model is tested to etermine the accuracy of an interregional model onstructed by "nesting" a subset of regions within larger closed system. Estimates of interregional rade are required for the approximation model.

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Interregional Feedback

Interdependence arises not only among sectors within a region but also among sectors between regions (Moses, Richardson). For example, an increase in demand for fed beef increases feedlot output in Oklahoma. Expansion in feedlot output increases the demand for feed grains from the Midwest, which, in turn, increases the demand for petroleum products produced in Oklahoma. Interregional feedback is this secondary trade effect in Oklahoma from an increase in final demand for fed beef. The first comprehensive accounting of commodity flows among states is recorded in Rodgers (1974). For the present study a three-region model is used. It is composed of separate regions for the states of Oklahoma and Texas and a third region, Rest of U.S. (RUS). The three-region trade model permits estimation of interregional feedbacks.

The principal data source is the MRIO model. The model affords both industrial and regional disaggregation, providing data for seventy-nine industry sectors and fifty-one regions. The data source covers the years 1947, 1958, 1963, 1970, and 1980. It is presented and documented in the five previously mentioned published volumes. A sixth publication, *A Guide for Users of the U.S. Multiregional Input-Output Model,* is also useful (Polenske 1972a). The model is flexible because of the level of disaggregation. The data are accessible and well-documented. Consistency with national aggregates in employment, output, final demand, and trade is maintained throughout. These features make it a useful model for the present study.

The authors have applied an aggregated version of the MRIO model to determine regional dimensions of U.S. agricultural growth and policy (Schreiner, Chang, Flood). In particular, the regional dimensions were the employment and income impacts on the southwestern states of Oklahoma and Texas of alternative growth and policy assumptions for U.S. agriculture. The National Economic Analysis Division (NEAD) of Economics, Statistics, and Cooperatives Service (ESCS) provided projections of alternative futures to 1980 and 1985 for U.S. agriculture based on different scenarios of growth in U.S. exports, population, and income (Smith et al.). The results of that study

(Schreiner, Chang, Flood) are not the focal point of this presentation. However, that study provides the model for testing interregional feedback and the results of an interregional approximation method.

The Model and Its Application

Regional input-output data are available in the format presented in Polenske (1972a). Total regional consumption (row total) for each sector is the sum of interindustry inputs, service industries residual, final demand, and secondary product transfer-out. The interindustry matrix is a seventy-nine-sector model. Service industries residual are the result of balancing total regional consumption with total regional output for those service sectors where regional trade was not estimated. The present study has used the regional trade data for sixty-one of the seventy-nine sectors.

Total regional consumption does not identify where products were produced. Hence, the row totals for each of the seventy-nine industry sectors are not necessarily equal to the corresponding column totals of regional output except for the nontraded service sectors.

Columns in the input-output table represent the regional input structure for each of the seventy-nine industry sectors. Total regional output (column total) is equal to regional production plus transferred imports, secondary product transfer-in, inventory depletion, and scrap production. Components of regional production are available in Rodgers (1972).

The columns of the regional input-output tables are defined on an establishment basis. The inputs purchased by a particular industry, therefore, consist of the amounts required to produce its primary and secondary outputs. Secondary products are double-counted to obtain an accounting balance, but with only a single column of transfer-out and a single row of transfer-in added to each regional input-output table (Polenske et al. 1974, p. 26). To balance the regional input-output tables with the regional trade matrices, the inventory depletion component of net inventory change is subtracted from final demand and added as a positive row. This adjustment is required to account for all shipments of a given commodity, regardless of the year in which it was produced (Polenske et al. 1972a, p. 29).

The technical coefficients are calculated from the regional input-output tables containing double counting of the secondary products. Each column of the regional input-output table is divided by the column total, adjusted to exclude inventory depletion, to obtain regional technical coefficients. The inventory depletion figures are not included in the column total since the technical coefficients should reflect inputs required to produce output of the current year. Thus, for the three regions of Oklahoma, Texas, and Rest of U.S., technology is represented as a partitioned matrix with the technical input-output coefficients for each region co tained on the diagonal:[1]

$$(1)\qquad \begin{bmatrix} A^{OK} & 0 & 0 \\ 0 & A^{TX} & 0 \\ 0 & 0 & A^{RUS} \end{bmatrix}.$$

A^{OK} thus represents the technical input-outp coefficients for Oklahoma with similar interpret tions of A^{TX} and A^{RUS} for Texas and Rest of U.S respectively. Each of these is a 79×79 submatri

Interregional commodity trade data are availabl on a region-by-commodity basis for each state an are published in Rodgers (1963). To maintain th balance between the regional input-output tabl and the regional trade tables, regional transfer-o is added to the respective control totals of the r gional trade tables. As employed here, region transfer-out is added to intraregional shipment Total regional consumption in the trade tables i then consistent with regional consumption in th input-output tables.

Trade coefficients, t_j^{km}, are computed by dividin the jth commodity flow from region k to region m r_j^{km}, by total regional consumption of commodity in region m, R_j^m. The trade coefficients includ intraregional flows. For the three-region model, total of nine trade matrices were computed an arranged in the following partitioned form:

$$(2)\qquad \begin{array}{r} \\ OK \\ TX \\ RUS \end{array} \begin{array}{c} \begin{array}{ccc} OK & TX & RUS \end{array} \\ \begin{bmatrix} T^{11} & T^{12} & T^{13} \\ T^{21} & T^{22} & T^{23} \\ T^{31} & T^{32} & T^{33} \end{bmatrix} \end{array}.$$

Each of the T^{km} matrices is a seventy-nine-secto diagonal matrix with the components equal t r_j^{km}/R_j^m. The matrices forming the princip diagonal identify intraregional shipments. Thu nontraded commodities are accounted for in thes matrices. In the off-diagonal matrices, nontrade commodities (sectors 61–79) receive a zero valu The Rest of U.S. region trade coefficients we aggregated from individual state commodity trad data. The interregional input-output coefficient m trix is computed as the product of the interregion trade matrix and the regional technology matrix:

$$(3)\qquad \begin{bmatrix} T^{11}T^{12}T^{13} \\ T^{21}T^{22}T^{23} \\ T^{31}T^{32}T^{33} \end{bmatrix} \begin{bmatrix} A^{OK} & 0 & 0 \\ 0 & A^{TX} & 0 \\ 0 & 0 & A^{RUS} \end{bmatrix} = \begin{bmatrix} B^{11}B^{12}B^{13} \\ B^{21}B^{22}B^{23} \\ B^{31}B^{32}B^{33} \end{bmatrix}$$

The B^{km} matrices give the regional source of th inputs described by the technical input-outpu coefficients. Hence, B^{21} shows the amount of input by sector coming from region two (Texas) per uni of sector output in region one (Oklahoma).

The complete interregional input-output model i expressed as

[1] The technology matrix A^{RUS} was not estimated directly. Se the next section on an interregional input-output approximatio model.

$$(4)\quad \begin{bmatrix} B^{11} & B^{12} & B^{13} \\ B^{21} & B^{22} & B^{23} \\ B^{31} & B^{32} & B^{33} \end{bmatrix} \begin{bmatrix} X^{OK} \\ X^{TX} \\ X^{RUS} \end{bmatrix} + \begin{bmatrix} T^{11} & T^{12} & T^{13} \\ T^{21} & T^{22} & T^{23} \\ T^{31} & T^{32} & T^{33} \end{bmatrix} \cdot \begin{bmatrix} Y^{OK} \\ Y^{TX} \\ Y^{RUS} \end{bmatrix} = \begin{bmatrix} X^{OK} \\ X^{TX} \\ X^{RUS} \end{bmatrix}.$$

Elements B and T are as previously defined. Final demand by region is represented by Y^{OK}, Y^{TX}, and Y^{RUS}. Multiplying the vector of regional final demands by the interregional trade coefficient matrix gives those portions of final demand coming from each region. Output by region is represented by X^{OK}, X^{TX}, and X^{RUS}. The output projection equation, suppressing regional identification, becomes:

$$(5)\quad (I - B)^{-1}TY = X,$$

where I is a unit matrix.

Richardson used a two-region, input-output model to illustrate the procedures of estimating interregional feedback. He excluded, however, the interregional feedback effects of final demand by using only Y rather than TY in (5). Expanding (5) to the two-region case gives

$$(6)\quad (I - B^{11})\Delta X^1 - B^{12}\Delta X^2 = T^{11}\Delta Y^1 + T^{12}\Delta Y^2$$

and

$$(7)\quad (I - B^{22})\Delta X^2 - B^{21}\Delta X^1 = T^{21}\Delta Y^1 + T^{22}\Delta Y^2,$$

where ΔX^k and ΔY^k refer to the change in total output and final demand in region k, respectively. Hence,

$$(8)\quad \Delta X^1 = [(I - B^{11}) - B^{12}(I - B^{22})^{-1}B^{21}]^{-1}[B^{12}(I - B^{22})^{-1}T^{21} + T^{11}]\Delta Y^1 + [(I - B^{11}) - B^{12}(I - B^{22})^{-1}B^{21}]^{-1}[B^{12}(I - B^{22})^{-1}T^{22} + T^{12}]\Delta Y^2.$$

Equation (8) gives the change in output of region one due to the change in final demand for both regions. Regional models assume $T^{km} = 0$ for all $k \neq m$. Under this assumption, equation (8) can be rewritten as

$$(9)\quad \Delta X^1 = (I - B^{11})^{-1}T^{11}\Delta Y^1.$$

Effects of feedback as proposed by Richardson are estimated by the difference between the first term of equation (8) (set $\Delta Y^2 = 0$) and equation (9).

In a closed interregional model the feedback effect of ΔY^2 on ΔX^1 must also be considered. If we assume a change in final demand for region two increases exports from region one (which is part of final demand for region one in a regional model) but do not allow for interregional feedback, then equation (9) is replaced by

$$(10)\quad \Delta X^1 = (I - B^{11})^{-1}T^{11}\Delta Y^1 + (I - B^{11})^{-1}T^{12}\Delta Y^2.$$

Total interregional feedback on ΔX^1 from ΔY^1 and ΔY^2 is then the difference between all of equation (8) and equation (10). It is this total interregional feedback that has been measured for Oklahoma in the three region model.

The difference in 1980 baseline output for selected sectors between the regional solution and the interregional solution for Oklahoma is shown in table 1.[2] This difference is attributed to interre-

[2] Sectors one and two (agricultural crops and livestock) have been excluded because in the original study these two sectors entered as predetermined output with interregional feedback already included in regional estimates of output (see Schreiner, Chang, Flood, pp. 26–31). The purpose of this study is to show the effects of interregional feedback using input-output models and exogenously determined agricultural output resulting from alternative assumptions concerning U.S. policy and growth in agriculture.

Table 1. Measurement of Interregional Feedback for Projected 1980 Baseline Output, Oklahoma, Selected Sectors ($1,000 in 1963)

Selected Sectors	Regional Output Solution	Interregional Output Solution	Interregional Feedback (2) − (1)	Percent (3) ÷ (1)
	(1)	(2)	(3)	(4)
59 Wholesale retail trade	2,468,177	2,500,142	31,965	1.3
71 Real estate, rental	2,214,945	2,305,599	90,654	4.1
11 New construction	1,497,345	1,497,345	0	0.0
31 Petro. related indus.	1,190,543	1,398,234	207,691	17.4
8 Crude petro. nat. gas	996,503	1,351,467	354,963	35.6
14 Food, kindred prodts.	927,924	997,355	69,430	7.5
65 Transp. warehousing	842,319	872,710	30,390	3.6
77 Med. educ. services	794,179	795,262	1,082	0.1
68 Elect. gas. san. serv.	718,393	743,041	24,647	3.4
60 Aircraft, parts	633,322	710,513	77,190	12.2
Total (10 sectors)	12,283,650	13,171,668	888,012	7.2
Remaining sectors (65)	5,934,123	6,606,811	672,626	11.3
All sectors (75)	18,217,773	19,778,479	1,560,638	8.6

Source: Schreiner, Chang, and Flood, p. 81.

gional feedback. Interregional feedback as a percentage of the regional solution is given in column (4) of table 1. The weighted average of interregional feedback for the ten nonagricultural sectors with the highest state output is 7.2%. Underestimation of sector output using the regional solution ranged from 0.0% in MRIO-11, new construction, to 35.6% in MRIO-8, crude petroleum and natural gas. The weighted average of interregional feedback for the remaining sixty-five nonagricultural sectors of the Oklahoma economy is 11.3%. The overall weighted average for the nonagricultural sectors is 8.6%. These results show that a regional input-output model for Oklahoma could underestimate sector outputs, and subsequent employment and income estimates, to a significant degree by not including interregional feedback.

Interregional Input-Output Approximation Model

The previous section has shown the importance of interregional feedback for the state of Oklahoma. Not many state and local research and planning agencies have the resources to finance a regional input-output model, let alone an interregional model. However, if an input-output model is available for the relatively closed system, i.e., the United States, and if trade estimates are available, a simplified model can be constructed. The simplified model assumes the region(s) of interest is (are) a small part of the overall closed system. Further, it is assumed that technology for the large remaining part of the closed system can be approximated by the technology of the entire closed system.

For the three region model described in the previous sections, an approximation model is tested that substitutes U.S. technology coefficients for A^{RUS}. All other data sets for Rest of U.S. region are aggregated from state data. That is, trade coefficients are built up from regional trade data, and final demand is calculated by subtracting Oklahoma and Texas data from national data. The purpose of the model is to approximate the structure of the remaining portion of the closed system as closely as possible without actually having to estimate the system.

The three region model is empirically tested using the 1963 MRIO base-year data.[3] If Oklahoma and Texas output accounts for a small share of U.S. output, the approximation model is expected to reproduce the original 1963 base-year output results fairly closely. Data for selected sectors on regional shares of national output and the percentage of error in reproducing regional output using the approximation model are presented in table 2. One sector in Oklahoma and seventeen sectors in Texas account for more than 5% of national output. Most of these sectors relate to petroleum mining and processing industries. Seven sectors in Oklahoma, ten sectors in Texas, and five sectors in Rest of U.S. region show an error of 5% or more in reproducing base-year output. Almost all of these sectors in Oklahoma and Texas include, or are highly interrelated with, petroleum mining and processing (MRIO-8, crude petroleum and natural gas; MRIO-27, chemicals and selected chemical products; MRIO-28, plastics and synthetic materials; MRIO-31, petroleum refining and related industries; MRIO-45, construction, mining, and oil field machinery and equipment).

Errors in reproducing both Oklahoma and Texas data are almost exclusively in the direction of overestimation of regional output. This would be ex-

[3] The MRIO model is a complete system with fifty-one regions. Hence, the need for an approximation model does not exist if all fifty-one regions are used. However, if analysis of but one or two regions in the MRIO system is needed or if such complete systems are not available, then the approximation model as proposed here becomes a feasible alternative.

Table 2. Validation Data of the Interregional Input-Output Approximation Model for Selected Sectors, 1963

	Regional Share of National Output (%)			Percentage of Error in Estimation of Base-Year Output Using Interregional Input-Output Approximation Model		
Selected Sectors	Oklahoma	Texas	Rest of U.S.	Oklahoma	Texas	Rest of U.S
69 Wholesale retail trade	1.03	5.02	93.95	0.68	1.05	−0.06
71 Real estate, rental	1.06	4.02	94.92	4.34	0.69	−0.14
11 New construction	1.48	6.17	92.35	0.0	0.0	0.0
31 Petro. related indus.	3.70	27.06	68.35	14.82	18.42	−8.32
8 Crude petro. nat. gas.	7.16	37.33	55.51	20.96	21.31	−19.60
14 Food, kindred prodts.	0.81	4.44	94.75	2.84	1.74	0.34
65 Transp. warehousing	1.25	5.81	92.93	1.95	3.81	1.70
77 Med. educ. services	0.63	3.02	96.35	0.15	0.21	0.01
68 Elect. gas. san. serv.	1.27	5.47	93.26	1.91	4.16	−1.89
60 Aircraft, parts	3.54	4.83	91.63	4.68	0.29	−0.93

Source: Schreiner, Chang, and Flood, p. 27.

pected, however, because the basic petroleum mining and processing sectors (MRIO-8 and 31) are overestimated and these two sectors are important components of the two state economies. Excluding results of petroleum-based sectors, the interregional input-output approximation model appears to be able to reproduce regional output data rather closely for the present regional delineation. However, the results also show that for regions with shares in excess of 5% of national output for any sector, a more critical evaluation should be made of the approximation model. In particular, the Rest of U.S. region technology should be adjusted to exclude the influence of the sector output accounted for in the study region(s).

Conclusions

The Multi-Regional Input-Output studies have been an asset to economists doing regional impact analyses. As similar national studies and updates occur, data will be improved and refined leading to increased confidence and usage of the data base by state and regional analysts.

Regional scientists realize that practically all national policies have differential impacts on states and regions. National policies and programs are evaluated on the basis of national benefits to achieve maximum social welfare. And this involves both equity and efficiency considerations. However, questions of economic efficiency and equity cannot be fully evaluated until the regional dimensions of national policy are specified. The regional dimensions of U.S. agricultural growth and policy are part of this overall evaluation. Beyond this, it is important to realize that planning is an ongoing process for regionally oriented public and private organizations. Thus the regional implications of national policies merit study if for no other reason than to provide these organizations the information necessary to anticipate needed adjustments and plan future investments. It is hoped that solid information of the regional impacts of national policy can act as a counterweight to the tendency to view regional differences as regional divisions (as may be the case in the discussion of national energy policy) by stressing the interrelatedness of regional economies.

Specification of regional impact models contribute to generation of solid information for policy evaluation. This study provides further evidence on the importance of interregional feedback in estimating regional impacts. But the cost of constructing the better specified interregional model may be too great. This study provides an approximation to the fully specified, interregional, input-output model utilizing available data bases from the MRIO studies. The state regional scientist can concentrate more on interpreting the issues facing his clientele group(s) and how best to integrate those issues into the interregional impact models.

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References

Moses, Leon. "A General Equilibrium Model of Production, Interregional Trade, and Location of Industry." *Rev. Econ. and Statist.* 42(1960):372–97.

Polenske, Karen R., Carolyn W. Anderson, and Mary M. Shirley. *A Guide for Users of the U.S. Multiregional Input-Output Model.* Prepared for the Office of Systems Analysis and Information, U.S. Department of Transportation. Washington, D.C., 1972a.

Polenske, Karen R., et al. *State Estimates of the Gross National Product 1947, 1958, 1963.* Lexington, Mass.: Lexington Books, 1972b.

Polenske, Karen R., et al. *State Estimates of Technology, 1963.* Lexington, Mass.: Lexington Books, 1974.

Richardson, Harry W. *Input-Output and Regional Economics.* Trowbridge Wiltshire, Great Britain: Redwood Press Limited, 1972.

Rodgers, John M. *State Estimates of Interregional Commodity Trade, 1963.* Lexington, Mass.: Lexington Books, 1974.

———. *State Estimates of Outputs, Employment, and Payrolls.* Lexington, Mass.: Lexington Books, 1972.

Scheppach, Raymond C., Jr. *State Projections of the Gross National Product, 1970, 1980.* Lexington, Mass.: Lexington Books, 1972.

Schreiner, Dean F., James C. Chang, and J. David Flood. *Regional Aggregate Economic Impacts from Alternative Futures for U.S. Agriculture.* Oklahoma State University Agr. Exp. Sta. Res. Rep. P-746, Feb. 1977.

Smith, Allen, Virden Harrison, Chung J. Yeh, Austin Fox, and Leroy Quance. *Projections of the U.S. Farm Subsector and Policy Implications.* ERS NEAD, Econ. Projections and Analytical Systems, Sept. 1974.

Specification Errors and Inference in Recreation Demand Models

Michael E. Wetzstein and John G. McNeely, Jr.

Recreation demand models are normally developed either for forecasting future demand or measurement of primary economic benefits of recreation facilities. A fundamental problem with the application of recreation demand models, based on the travel cost approach, is the difficulty of capturing effectively the price of a recreation experience. Distance, travel cost, monetary cost (travel cost plus other variable cost), and travel time have been incorporated into various demand functions (Cesario, Gum and Martin, and Sinden). The present paper discusses a number of proposed demand specifications and investigates alternatives for incorporating price surrogates. Specifically, ski data collected over California and Nevada ski resorts were applied to alternative model specifications.

Demand Specification

Three multiplicative model specifications generally have been employed to estimate recreation demand models (Cesario; Cicchetti, Fisher, Smith; McConnell; Wilson):

(1) $$v_{ij} = A x_{1ij}^{\beta_1} \exp^{\mu_{ij}},$$

(2) $$v_{ij} = A x_{2ij}^{\beta_2} \exp^{\mu_{ij}},$$

(3) $$v_{ij} = A x_{1ij}^{\beta_1} x_{2ij}^{\beta_2} \exp^{\mu_{ij}},$$

for $i = 1, \ldots, I$, $j = 1, \ldots, J$, and where v_{ij} is the number of visits incurred by individual or origin "i" to area "j";[1] x_{1ij} is the total monetary cost, travel cost plus other variable cost, for individual or origin "i" to participate at area "j"; and x_{2ij} is the distance between an individual's residence or origin "i" and area "j."[2]

Distance or cost have been employed in various recreation models as price surrogates in the form of specifications (1) and (2). Theory suggests, however, that disutility of overcoming distance is not cost alone but also time involved in making the trip (Cesario and Knetsch; McConnell). Thus, both variables have been incorporated into a single model where cost and distance are surrogates for price and time allocation, respectively, specification (3). This would then allow the effects of time and cost to be separated and the impact of cost on use could be evaluated. Cost and time are, however, normally highly correlated for most outdoor recreation observations, and thus, the variables have been combined into a single interacting variable (Cesario; Cesario and Knetsch).

A disadvantage of the single interacting variable, as stated by Brown and Nawas, is the implicit assumption that one or more specific trade-offs exist between cost and time. Thus, researchers are confronted by multicollinearity if they incorporate both cost and time in a model specification (3), and specification error if they only incorporate either cost or time, specification (1) or (2). In addressing this problem Brown and Nawas increase sample size by employing observations across individuals rather than origin or county zones. This allows distance traveled to be used as a surrogate variable for travel time. Another problem with employing aggregated data is the loss of efficiency in the cost coefficient by aggregating over distance instead of cost. Past empirical estimates of outdoor recreation demand are usually based on data aggregated in distance zones which is a highly efficient grouping scheme for distance but not for monetary cost.

Efficient Method of Grouping

Brown and Nawas provide one solution, disaggregation, that may solve the dilemma of multicollinearity and specification error. In a case where aggregation is necessary to avoid large-scale computations, however a researcher is still confronted with the problem of multicollinearity and specification error. Efficient grouping of the cost variable, by aggregating observations by cost instead of time (distance), will provide a more efficient estimate of the coefficient associated with cost and thus improve the confidence in the value of the coefficient. In addition, grouping observations by cost may reduce the bias from errors in the explanatory variable (Johnston).

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[1] Number of visits is specified as the dependent variable instead of visitor days. For a discussion of which specification is appropriate, see McConnell.

[2] For a complete specification of the model, variables accounting for income allocated to recreational activities and prices of substitutes would be required. These variables were not introduced into the model because the focus of this paper is a discussion of the relationship between cost and time, not the development of a full demand model. Exclusion of these variables are not expected to alter results and conclusions.

Prais and Aitchison present an extensive discussion of grouping units which are as homogenous as possible in order to obtain more efficient estimators. Recent research has provided various criteria for grouping data into homogenous units. (For examples, see Cox; Friedman and Rubin; O'Neill and Wells; Ward.) All the criteria for efficient grouping of data attempt to minimize the variable sum of squares within groups. Aggregating over costs versus distance would minimize the sum of squares of the cost variable within groups compared to aggregating over distance. Therefore, aggregating observations over cost leads to more efficient estimates of the cost coefficient, as illustrated below.

Results of Analysis

A logarithmic transformation of the three demand models were estimated employing ski survey data collected over the 1976–77 ski season for eleven California and Nevada ski areas. A total of 784 individual observations, disaggregated data, collected over the eleven ski resorts, were used to estimate (by ordinary least-squares) the parameters of specifications (1), (2), and (3). Observations were then aggregated into fixed-interval groups over both cost and distance. The aggregated data were estimated by applying weighed least-squares to specification (3). Weighted least-squares was applied in this case because heteroskedasticity is present in the aggregated data. Heteroskedasticity results when the number of observations is not identical in every group (Kmenta, pp. 322–28).

Results of estimating the specifications employing individual and aggregated observations are presented in table 1. The overall goodness of fit $\bar{R}^2$ between aggregated and individual observations reflects the situation that aggregated means tend to be less dispersed around the fitted regression line than the individual observations (Cramer).

The monetary cost and distance coefficients are negative in every case which is consistent with a priori expectations. Furthermore, the t-values indicate that all coefficients are highly significant except those associated with monetary cost for equations (3) and (3′). The coefficients associated with cost in equation (3) and (3′) are significantly different from zero at the 0.32 and 0.45 level, respectively.

The large standard errors associated with the monetary cost coefficients in equations (3) and (3′) are due to the relatively high intercorrelation between monetary cost and distance in these two equations. The correlations between monetary cost and distance in equations (3) and (3′) are 0.59 and 0.83, respectively.

When the data are aggregated by monetary cost both monetary cost and distance coefficients are significantly different from zero at the .05 level (see table 1). The standard errors associated with the coefficients in equations (3′) and (3″) are, however, in all cases greater than those associated with the disaggregated estimates. In fact this is always the case. That is, the variances of the estimators based on grouped data can not be less than those of the estimators based on the disaggregated observations (Prais and Aitchison). The results presented in table 1 do indicate that the estimates of the coefficients are more efficient in equation (3″) than in equations (3) and (3′). This result is of particular importance when the modeling objective is for measurement of primary economic benefits.

Table 1. Estimated Demand Models for Disaggregate and Aggregate Specifications

	Equations				
				Aggregated over Distance	Aggregated over Monetary Cost
	1	2	3	3′	3″
Estimation technique	OLS[a]	OLS	OLS	WLS[b]	WLS
Constant	1.881[c]	2.643[c]	2.642[c]	3.703[c]	4.048[c]
	(0.082)[d]	(0.124)	(0.124)	(0.205)	(0.503)
Monetary cost	−0.215[c]		−0.051	−0.112	−0.314[c]
	(0.029)		(0.035)	(0.107)	(0.130)
Distance	·	−0.289[c]	−0.261[c]	−0.332[c]	−0.214[c]
		(0.026)	(0.037)	(0.063)	(0.068)
Degrees of freedom	784	784	783	54	56
$\bar{R}^2$[e]	0.064	0.132	0.134	0.294	0.342

[a] Ordinary least-squares.
[b] Weighted least-squares.
[c] Significantly different from zero at the 0.05 level.
[d] Numbers in parentheses are standard errors.
[e] $\bar{R}^2$ is the adjusted R^2 value.

Summary and Implications

Aggregating over cost versus distance provides an alternative model specification where disaggregation is not feasible or does not elevate a problem of multicollinearity. This paper illustrates that a model specification incorporating aggregated data over cost does result in more efficient estimates of the coefficients, as suggested by previous research in grouping of observations. Simulation results performed on the estimated equations indicated that aggregating data over cost generally provided a more efficient estimate of the cost coefficient compared to aggregating by distance. The cost coefficient was significantly different from zero in all these simulations when the data are aggregated by cost; however, only 84% of the coefficients are significantly different from zero when the data are aggregated by distance. Although this method may not be suitable in all cases it is an alternative specification worth investigating.

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References

Brown, W. G., and F. Nawas. "Impact of Aggregation on the Estimation of Outdoor Recreation Demand Functions." *Amer. J. Agr. Econ.* 55(1973):246–49.

Cesario, F. J. "Value of Time in Recreation Benefit Studies." *Land Econ.* 52(1976):32–41.

Cesario, F. J., and J. L. Knetsch. "Time Bias in Recreation Benefit Estimates." *Water Resour. Res.* 6 (1976):700–04.

Cicchetti, C. J., A. C. Fisher, and V. K. Smith. "An Econometric Evaluation of a Generalized Consumer Surplus Measure: The Mineral King Controversy." *Econometrica* 44(1976):1259–76.

Cox, D. R. "Note on Grouping." *J. Amer. Statist. Assoc.* 52(1957):543–47.

Cramer, J. S. "Efficient Grouping, Regression and Correlation in Engle Curve Analysis." *Amer. Statist. Assoc.* 59(1964):233–50.

Friedman, H. P., and J. Rubin. "On Some Invariant Criteria for Grouping Data." *J. Amer. Statist. Assoc.* 62(1967):1159–78.

Gum, R. L., and W. E. Martin. "Problems and Solutions in Estimating the Demand for and Value of Rural Outdoor Recreation." *Amer. J. Agr. Econ.* 57 (1975):558–66.

Johnston, C. J. *Econometric Methods.* New York: McGraw-Hill Book Co., 1972.

Kmenta, J. *Elements of Econometrics.* New York: Macmillan Co., 1971.

McConnell, K. E. "Some Problems in Estimating the Demand for Outdoor Recreation." *Amer. J. Agr. Econ.* 57(1975):303–34.

O'Neill, B., and W. T. Wells. "Some Recent Results in Log-Normal Parameter Estimation Using Grouped and Ungrouped Data." *J. Amer. Statist. Assoc.* 67(1972):76–80.

Prais, S. J., and J. Aitchison. "The Grouping of Observations in Regression Analysis." *Rev. Int. Statist. Inst.* 22(1954):1–22.

Sinden, J. A. "A Utility Approach to the Valuation of Recreational and Aesthetic Experiences." *Amer. J. Agr. Econ.* 56(1974):61-72.

Ward, J. H., Jr. "Hierarchical Grouping to Optimize an Objective Function." *J. Amer. Statist. Assoc.* 58(1963):236–44.

Wilson, R. R. "Consumer Behavior Models: Time Allocation, Consumer Assembly, and Outdoor Recreation." *An Economic Study of the Demand for Outdoor Recreation*, pp. 16–18. Coop. Reg. Res. Tech. Comm. Rep. No. 2. Reno, Nev., 1970.

Expected Benefits from Nonchemical Methods of Alfalfa Weevil Control

Luis R. Zavaleta and William G. Ruesink

The problem of managing insect pests has been receiving increased interest as a part of the technological revolution that has dramatically increased agricultural output.[1] During the past few decades, several biological and cultural methods of pest control have been conceived and/or implemented, e.g., DeBach, Huffaker (1971, 1980), Huffaker and Messenger, Metcalf and Luckmann, Reichelderfer and Bender. However, contemporary technology has analyzed and relied heavily on the use of synthetic chemical pesticides (Hall and Norgaard; Regev Gutierrez, Feder; Talpaz and Borosh; Talpaz et al.). The preference for chemical control is derived, in most cases, from its achievement of satisfactory control at relatively low costs.

However, the intensive, as well as extensive, uses of synthetic organic pesticides, in particular a few persistant insecticides such as DDT and BHC, have had detrimental effects on the quality of the environment. Prolific use of chemical pesticides develops genetic pest resistance, changes pest complexes by affecting nontarget populations and allowing outbreaks of secondary pests, and affects the ecosystem with its residues in feeds, foods, and organisms (Shoemaker). Policymakers have reflected the concern of society for environmental contamination by legislation restricting pesticides, suggesting that future pest control cannot solely depend upon routine applications of insecticides.

This note investigates the potential gains that may be derived from the use of biological means of control as well as the introduction of a host plant with added resistance (antibiosis) against the alfalfa weevil (*Hypera postica*). This insect contitutes one of the more important insect pests of alfalfa and can cause large losses in yield or even death of the crop if uncontrolled (Armbrust and Gyrisco).

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[1] The term "pest" is a rational abstraction with no ecological inference. Its existence, however, indicates that the insects are regarded as destructive or noxious in proportion to the number present and that it is in direct competition with man for a set of limited resources (Headley and Lewis; Metcalf and Luckmann).

Model Description and Procedure

Our study used the computerized models developed for the alfalfa crop (Fick) and for the alfalfa weevil (Ruesink). More complete versions of these models have been provided by the authors; therefore, this presentation is limited to a brief discussion of the relevant components and those elements not explicitly addressed in available descriptions.

The dynamic computer model of the alfalfa crop mimicked the daily time path of state variables such as the biomass of leaves, stems, buds, and total nonstructural carbohydrates (TNC) as a function of environmental conditions. To simulate other conditions, such as the harvesting of the crop, the state variables for leaves and stems were set to zero, following which regrowth was achieved by a flow of materials from buds and TNC into leaves and stems. New material was generated by photosynthesis. The rates of flow between components and the rate of photosynthesis were modeled as functions of light intensity, day lengths, temperatures, and the values of the state variables. The model assumed adequate soil moisture, high levels of fertility, and absence of pest problems other than the *Hypera postica*. In actual field conditions, more than one pest may be found; however, to keep the problem computationally manageable attention was directed to the alfalfa weevil.

The alfalfa weevil system was modeled using thirteen components, while the parasite system used three. For example, in figure 1, the alfalfa weevil has components for egg (E), four larval instars (L_1 through L_4), pupa (P), and adult stages (A_0, A_{f1}, A_{f2}, A_d). The parasite was modeled as having a cocoon (C), diapausing (D), and adult (A) stages. In this model, the state variables describe the number of individuals present in that life stage. Flows were unidirectional in that an individual could only become more mature in its lifetime. For each of the components of this system, there are response functions in difference equation form using a one-day time step. The rates of flow between components and the rates of reproduction were modeled as functions of temperature, day length, and the values of other key state variables.

Both models, the alfalfa plant growth and the insect component, are interfaced through a trophic process (*FEEDING*, in fig. 1). The potential rate of feeding by the weevil was modeled as proportional

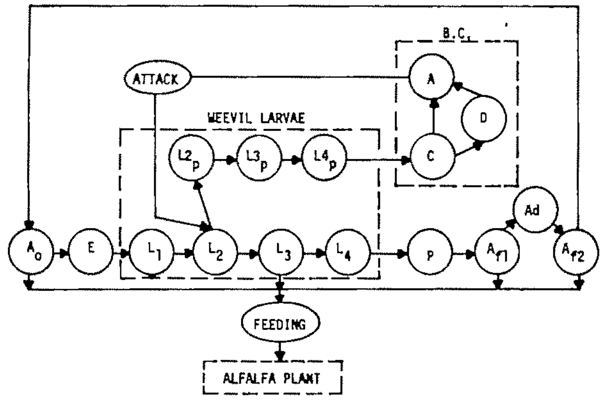

Figure 1. Diagrammatic model of the alfalfa weevil and *B. curculionis* life systems. (From Ruesink, copyright 1976, Board of Trustees, Michigan State University. Reprinted by permission.)

to the average developmental rate per instar, but this rate was allowed to vary from day to day with temperature variations. The actual feeding rate for each instar and the adult stages at time *t* was assumed a function of the ratio between available biomass and the estimated potential feeding rate. The interaction between *B. curculionis* and the weevil larvae was modeled through the trophic process denoted *ATTACK* (fig. 1). Through this process, a certain percentage of the larval population in the second stage is parasitized ($L2_p$) and remains as such during the third and fourth stages ($L3_p$ and $L4_p$, respectively), reaching death during the latter instar.[2] The beneficial effects of the parasite were obtained through an induced reduction on feeding rates for the larval stages and through an increase in the mortality rate of the weevil.

For the present analysis, records of ten years were used for each of four weather stations, selected as representative of major alfalfa growing regions in the eastern United States. They were Ithaca, New York; Bedford, Virginia; Rochester, Minnesota; and Nashville, Illinois. For the period of analysis, daily maximum and minimum temperatures and solar radiation were required. It was also necessary to indicate which biotype of the alfalfa weevil was being simulated, because the eastern and western population of this species do have a few differences that are not explainable by differences in climate.

The model was initialized on 1 September, because at that time most of the alfalfa weevil are diapausing adults. Hence the insect portion of the model could be initialized by assigning nonzero densities to these state variables and setting the remaining at zero. Therefore, in the simulation runs for each locality, the initial weevil density was set at $10/m^2$, which is typical of a moderately heavy infestation. In those cases where parasities were included, their initial density was set at $2/m^2$, which is a rather low population level for that species. These initial conditions were used in the simulation models to provide results that may be considered as conservative values to be expected from these control actions.

Finally, the model recorded an insecticide application whenever the density of third and fourth instar weevil larvae exceed $400/m^2$, which corresponds approximately to the economic injury level recommended in Illinois (Wedberg et al.).[3]

Changes in yield, insecticide use, and their monetary values were computed by comparing ten-year averages for a normative benchmark solution to averages obtained for different elements integrated in pest management methods. Specifically, the normative benchmark solution considered the application of chemicals as the only means of pest control. The results thus obtained were used to measure the benefits that may have been derived from integrating (*a*) biological and chemical controls, and (*b*) biological, cultural, and chemical practices.

Value of the Parasite

This analysis examined the impact of *B. curculionis* at an initial density of $2/m^2$. From this initial density, the population was allowed to develop naturally for the following ten years. The effects that the parasite may have on the weevil population were, among other factors, dependent on the levels as well as on the synchrony of the cyclical fluctuations on population. Therefore, when the parasite did not perform an adequate job in controlling the weevil, the use of an insecticide was simulated at the time the economic injury level was achieved by the *Hypera postica* population. In this case it was considered that the insecticide affected only the mortality rates of the two insect species but did not interfere with the efficiency or behavioral attack of the parasite. The assumption of noninterference was made since at the present time there are no data that will contradict it.

As a result, it was found that the use of this integrated approach improved the yields obtained by reducing the damage, compared to those values reached by means of chemical control only. These values, however, varied among regions (table 1). For Illinois and Virginia, alfalfa yields were increased by 130 and 230 kilograms per hectare (kg./ha.), respectively; while in the northern states of Minnesota and New York, the increase was of 100

[2] The *B. curculionis* also attacks the third instar weevil larvae; however, its effects compared to the attack on the second instar were found to be of relative insignificance. Therefore, it was not explicitly modeled.

[3] The economic injury level is considered to be the lowest population level capable of creating a crop damage that will equate or exceed the cost of taking a control measure.

Table 1. Value of the Parasite, *Bathyplectes curculionis*, in Reducing Losses to Alfalfa Weevil in the Eastern United States

Annual Average[a]	Ithaca, New York	Bedford, Virginia	Nashville. Illinois	Rochester, Minnesota
Increased yield (T/ha)	.10	.23	.13	.10
Reduced insecticide use (no. applications)	.20	.90	.75	.10
Value of increased yield ($/ha)	5.00	11.50	6.50	5.00
Value of saved insecticide ($/ha)	3.00	13.50	11.25	1.50
Total economic value	8.00	25.00	17.75	6.50

[a] Alfalfa hay is valued at $50/T and insecticide is estimated to cost $15/application/ha.

kg./ha. The data presented in table 1 show that the introduction of the parasite not only had the effect of reducing the amount of yield damaged by the weevil (or to increase yield), but it also reduced the amount of insecticide applications required.

For the latter, the southern areas were the most benefited by the existence of the parasite. This improvement could be attributed to more favorable climatic conditions for the development of the *B. curculionis* than those existing in the northern states. As a result, the value of the saved insecticide in these areas exceeded the value of increased yield; while in the northern areas, the major benefits are derived from increased yields. When these data are evaluated for the eastern United States, they suggest that the parasite could save about $44 million per year as compared to the benchmark case. It should be pointed out that the predicted increase in production represents less than 1% of the total crop, and this increase would not be expected to influence the market price for alfalfa hay. In addition to its economic impact, this approach could account for a great reduction in pesticide use. About 1,100 tons per year less insecticide would be necessary than in the case where only chemical control is employed. This reduction in pesticide input to the environment deserves attention beyond its economic value.

Value of Host Plant Resistance

Another method of pest management is the use of cultural practices. These practices may involve, among others, adjusting the date of harvest as well as introducing the use of plants that are genetically resistant to the weevil. As described by Kogan, "Resistance to insects is the property that enables a plant to avoid, tolerate, or recover from injury by insect populations that would cause greater damage to other plants of the same species under similar environmental conditions. This property generally derives from certain biochemical and/or morphological characteristics of plants which so affect the behavior and/or the metabolism of insects as to influence the relative degree of damage caused by these insects" (p. 103).

At the present time, there are no commercially available alfalfa varieties that have resistance to the alfalfa weevil. Plant breeders have had little success at finding genetic material that carries the level of resistance they seek. The following analysis was performed to quantify the value of partial resistance, and the results should provide the breeders with incentive to develop varieties with even a small amount of resistance.

The particular type of resistance considered here is known as antibiosis, in which some characteristic of the plant causes a reduction in survival of the pest population. This analysis assumes the development of a variety that causes mortality to the first larval instar of the weevil but that has no other direct impact on either the weevil or its parasite. Specifically, 20, 40, 60, and 100% additional mortality levels were evaluated. The data presented in table 2 consider the presence of *B. curculionis* and *Hypera postica* at the same initial population densities described previously.

The use of a truly resistant plant—one on which the pest cannot (or will not) live, represented here by the 100% added mortality case—would increase average yields about .35 tons per hectare. This increase corresponds to a total value of $89 million per year. At the same time, insecticide use would be reduced to zero. These savings are not spread equally over the four regions. The south-central area would benefit only $13.50 per hectare, while in the other areas the benefits range from $16 to $18.50 per hectare. The primary reason for the smaller benefit from plants with added mortality in the south-central region is that the parasite, according to these simulations, is already doing a good job of controlling the weevil.

If, instead of total resistance, the breeders only achieved 60% added larval mortality, insecticide use still would decline to zero, but a small amount of damage to alfalfa would continue to occur. Under these conditions the damage is too small to justify the expense of insecticide application. Thus, 60% added mortality is nearly as beneficial as 100%.

Table. 2. Value of Host Plant Resistance in Reducing Losses to Alfalfa Weevil in the Eastern United States

Annual Average[a]	Benchmark	Level of Added Mortality (%) 20	40	60	100
	Northeast U.S. (0.8 million ha.)				
Yield (T./ha.)	14.07	14.22	14.35	14.38	14.39
Insecticide used (kg./ha.)	.70	.20	0	0	0
Reduced damage ($mil./region)		6.00	11.20	12.40	12.80
Reduced insecticide (T./region)		400.00	560.00	560.00	560.00
	Southeast U.S. (0.1 million ha.)				
Yield (T./ha.)	19.43	19.61	19.68	19.75	19.77
Insecticide used (kg./ha.)	1.20	.10	0	0	0
Reduced damage ($mil./region)		.90	1.25	1.60	1.70
Reduced insecticide (T./region)		110.00	120.00	120.00	120.00
	North Central U.S. (3.5 million ha.)				
Yield (T./ha.)	13.72	13.83	13.97	14.04	14.09
Insecticide used (kg./ha.)	.70	.40	.10	0	0
Reduced damage ($mil./region)		19.25	43.75	56.00	64.75
Reduced insecticide (T./region)		1,050.00	2,100.00	2,450.00	2,450.00
	South Central U.S. (0.7 million ha.)				
Yield (T./ha.)	18.31	18.42	18.45	18.57	18.58
Insecticide used (kg./ha.)	1.625	.625	.25	0	0
Reduced damage ($mil./region)		3.85	4.90	9.10	9.45
Reduced insecticide (T./region)		700.00	963.00	1,138.00	1,138.00
	Total for Eastern Half of the U.S. (5.1 million ha.)				
Reduced damage ($ million)		30.00	61.10	79.10	88.70
Reduced insecticide (T.)		2,260.00	3,743.00	4,268.00	4,268.00

[a] Alfalfa hay is valued at $50/T. and insecticide is estimated to cost $15 application/ha.

In the cases where 40% added mortality were attained, the value of production would increase by $61 million per year, and insecticide use would decrease by 3,743 tons per year. In this case, some insecticide still would be used in the Midwest each year, but it would be 85% below the present use rate. East of the Allegheny Mountains, no insecticide would be needed.

Finally, if only 20% mortality were added to the first larval instar, the value of production in the eastern United States could be increased by $30 million per year, and insecticide use could decrease by 2,260 tons a year. Although these figures are far inferior to the 40% case, producers and environmentalists would welcome this improvement.

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References

Armbrust, E. J., and G. G. Gyrisco. "Forage Crop Insect Pest Management." *Introduction to Insect Pest Management,* eds. R. L. Metcalf and W. H. Luckmann, pp. 445–69. New York: John Wiley & Sons, 1975.

DeBach, P., ed. *Biological Control of Insect Pests and Weeds.* New York: Reinhold, 1964.

Fick, G. W. *ALSIM (Level 1)–User's Manual.* Dep. of Agronomy 75-20, Cornell University.

Hall, D. C., and R. B. Norgaard. "On the Timing and Application of Pesticides." *Amer. J. Agr. Econ.* 55(1973):198–201.

Headley, J. C., and J. N. Lewis. *The Pesticide Problem: An Economic Approach to Public Policy.* Washington, D.C.: Resources for the Future, 1967.

Huffaker, C. B., ed. *Biological Control.* Proceedings of an AAAS Symposium on Biological Control, Boston Mass., 30–31 Dec. 1969. New York: Plenum Press, 1971.

———. *New Technology of Pest Control.* New York: John Wiley & Sons, 1980.

Huffaker, C. B., and P. S. Messenger, eds. *Theory and Practice of Biological Control.* New York: Academic Press, 1976.

Kogan, M. "Plant Resistance in Pest Management." *Introduction to Insect Pest Management,* eds. R. L. Metcalf and W. H. Luckmann, pp. 103–46. New York: John Wiley & Sons, 1975.

Metcalf, R. L., and W. H. Luckmann, eds. *Introduction to Insect Pest Management.* New York: John Wiley & Sons, 1975.

Regev, U., A. P. Gutierrez, and G. Feder. "Pests as a Common Property Resource: A Case Study of Alfalfa Weevil Control." *Amer. J. Agr. Econ.* 58(1976):186–97.

Reichelderfer, K. H., and F. E. Bender. "Application of a Simulative Approach to Evaluating Alternative Methods for the Control of Agricultural Pests." *Amer. J. Agr. Econ.* 61(1979):258–67.

Ruesink, W. G. "Modeling of Pest Populations in the

Alfalfa Ecosystem with Special Reference to the Alfalfa Weevil." *Modeling for Pest Management*, eds. R. L. Tumala, D. L. Haynes, and B. A. Croft, pp. 80–89. East Lansing: Michigan State University Press, 1976.

Shoemaker, C. "Optimization of Agricultural Pest Management I: Biological and Mathematical Background." *Mathematical BioSciences* 16(1973):143–75.

Talpaz, H., and I. Borosh. "Strategy for Pesticide Use: Frequency and Applications." *Amer. J. Agr. Econ.* 56(1974):769–75.

Talpaz, H., G. L. Curry, P. J. Sharpe, D. W. DeMichele, and R. E. Frisbie. "Optimal Pesticide Application for Controlling the Boll Weevil on Cotton." *Amer. J. Agr. Econ.* 60(1978):469–75.

Wedberg, J. L., W. G. Ruesink, E. J. Armbrust, and D. P. Bartell. *Alfalfa Weevil Pest Management Program.* University of Illinois Coop. Extens. Serv. Circ. 1136, 1977.

A Proposal to Further Increase the Stability of the American Grain Sector

J. R. Groenewegen and W. W. Cochrane

This paper presents a policy proposal which is designed to complement current agricultural legislation in its attempt to stabilize the United States grain sector. Price and income stability is important to commercial agriculture and consumers (e.g., see Brandow), has been of central concern in past agricultural legislation (Cochrane and Ryan), and will, in all likelihood, continue to be on the legislative agenda in one form or another. The proposal advanced in this paper is predicated on the following statements:

First, the programs and instruments contained in the 1977 Food and Agriculture Act are adequate for stabilizing prices between the loan rate and the farmer-held reserve release rates when global production does not significantly veer below trend for grain crops. The target price deficiency payment scheme is also deemed adequate for protecting income levels. (For details and discussion on the 1977 Act, see U.S. Department of Agriculture, Spitze.) But it is our assertion that the existing programs in their present form are not adequate for protecting the long-run interests of American consumers and producers in periods when global production does drastically veer below trend (e.g., the production shortfalls as witnessed in 1972/73).

Second, major importers of grains, such as the EEC, Japan, the USSR, and China, insulate their agricultural sectors from the world grain market. These insulation policies exaggerate the price adjustments required by countries openly linked to the world market. (See Johnson, Grennes, Thursby; and Nelson for a discussion of these operational instruments for Japan and the EEC. D. G. Johnson provides a description of agriculture and agricultural policies in the Soviet Union.)

Third, prices for agricultural products in the United States, especially grain products, would not have reached the high levels of the early seventies if the major importers, instead of maintaining their protective and insulating policies, had adjusted internal prices in accordance with world conditions at that time.

Fourth, in this same era price advances also would have been more moderate if a system of national grain reserve stocks had been in operation with the objective of stabilizing world grain prices.

Fifth, the theoretically appealing concept of free trade, as a means to stabilize international grain markets, is not proposed as the means to stability because most nations control their agricultural sectors and thereby insulate those sectors from world conditions, and those nations are not willing to forfeit that control.

Sixth, the United States is the predominate supplier of grains to the world market; it is openly linked to the world grain market while the major grain importers (and some exporters) insulate their agricultural sectors from this market; and, as a result, it assumes a disproportionate share of the stock and price adjustment when world grain conditions change.

Seventh, the viability of present-day American agriculture depends heavily on the exportation of grain and its products. A policy of domestic agriculture maintaining a direct open link with the world grain market (i.e., export competitiveness) benefits domestic agriculture by maintaining and expanding grain exports; but when taking into consideration the five previous statements, then this policy conflicts with the objective of stable grain prices.

Eighth, therefore, if it is in the national interest to avoid repercussions of global grain shortages which are beyond the boundaries of protection provided by current legislation, then the United States could if it wished, stabilize its domestic agriculture by (*a*) insulating its grain sector from abnormal world conditions and (*b*) inducing grain importers to undertake some of the required adjustment in world grain utilization.

With these statements as a background setting to the stability problem under consideration, the policy proposal is presented in the next section. The subsequent section focuses on implications of this proposal and also highlights some empirical questions that should be addressed before implementation of this proposal is considered.

Policy Proposal

It is proposed in this paper that the United States insulate in a certain price range and to a reasonable degree its domestic grain sector from extreme destabilizing world market forces but, at the same

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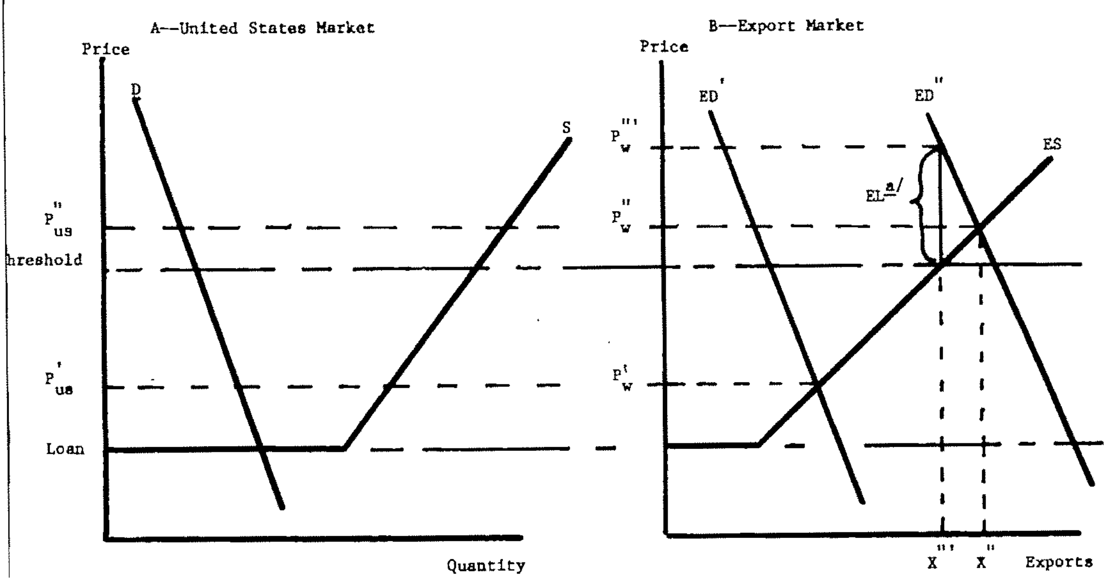
time, maintain its position as a dependable supplier of grains. The achievement of these two procedural objectives can be achieved, it is argued here and throughout the paper, without seriously compromising either of the seemingly conflicting goals of market stability and export competitiveness. This proposal, it must be repeated, does not completely insulate U.S. agriculture; it is designed only to insulate this sector when world shortages are so acute that the stabilizing instruments of the 1977 Food and Agriculture Act are ineffective. Granted this acute global shortage may never again occur; but if this did occur, then U.S. agriculture would again be required to make unnecessary and undesired adjustments. When price is close to its equilibrium value, then the proposal does not restrict price from performing its various functions in the world grain market that it does most efficiently.

For the proposal under consideration here to be effective, policy instruments, in addition to those contained in the current program, are required for the American grain sector to insulate itself from extremely high prices, to maintain the position as a dependable supplier, and to be responsive to a long-term trend. These additional instruments, which are discussed below, are variable export levies, bilateral agreements with importers, a global allocation system, and a domestic grain reserve.

Variable Export Levy

The variable export levy is included to ensure that domestic prices never will exceed a threshold level. A system of variable export levies serves to insulate American consumers and producers from extreme external price rises in the same manner as loan rates give downward price protection. Given existing legislation the maximum domestic price (the threshold price) allowed could be set, for example, 150% of loan at the discretion of the Secretary of Agriculture. This threshold value must exceed the equilibrium price level. Also, consistency with the farm reserve program requires that the threshold price be at least as great as the level at which the secretary can call the loan. Threshold prices for grain products would be determined by establishing grain equivalents for these products. Grain prices would be stabilized in a band between the loan rate and the threshold price. Corn prices, therefore, could vary between \$2.00 (loan) and \$3.00 (150% of loan) per bushel. Domestic prices would remain at the threshold price whenever the world price rose above the threshold level, as a consequence of the operation of the variable export levy in conjunction with an allocation system and a bilateral trade agreement system, both of which are discussed in the next section. In this case, the export levy would be the difference between the world price and the threshold price. Figure 1 illustrates just the influence of the levy on domestic and world prices. Panel A in figure 1 represents a hypothetical supply (S) and demand (D) condition for the United States. Panel B shows the excess supply (export) function for the United States (ES) and the net import demand function for the rest of the world (ED). (For a discussion on excess supply and demand functions, see Bressler and King.) When import demand is ED', the world price (P_w') and the U.S. price (P_{us}') are identical. Without an export levy, an increase in world demand to ED'' increases the world price and the domestic price to P_w'' and P_{us}'', respectively. Implementation of an export levy (EL) whenever



a/ Export levy.

Figure 1. Export levy on United States grain exports

price is above threshold maintains the domestic price at the threshold price and for the above example increases the world price P_w^{m}. In this case U.S. export volume decreases from X^{n} to X^{m}.

When world price is above threshold, exporters could purchase grain at threshold and sell at the world market price, so long as the domestic and bilateral agreement allocations were not infringed upon. Export companies would submit levy proceeds to a government agency, such as the Commodity Credit Corporation (CCC), which would also monitor export sales. These funds would be used to finance CCC operations or other farm programs. The export levy would need to be adjusted continuously in accordance with world market developments because, if the levy is too small, export companies would gain windfall profits since supplies are purchased at threshold; if the levy is too large, exporters would be losing money on export sales. The propensity for internal prices to rise above the threshold price would be moderated because exporters would not bid more than the threshold price for grain, unless they were willing to encounter a loss when submitting levy receipts. The global allocation system which is discussed in a subsequent section also prevents this type of price rise.

This program, while designed to insulate the domestic economy, would be flexible enough to respond to price trend between crop years. The Secretary of Agriculture could increase the threshold price by 10% whenever domestic price is 95% of threshold, or more. If the threshold price is increased, but domestic price is less than 95% of the former threshold value, then the subsequent threshold price could decrease to its former value.

Variable export levies, it can be argued, are not compatible with American food and agricultural goals in two respects. First, total world trade declines with an effective levy, since by insulating itself, the American grain sector does not adjust consumption and production, and hence, exports to world developments. Second, this reduction in world trade results in a higher world price when the levy is in force, as illustrated in figure 1. Both of these side effects of the proposed policy run counter to the goal of a dependable supplier of grains. But a system of bilateral agreements and domestic reserve programs could be employed to circumvent these disadvantages.

Bilateral Agreements

Bilateral agreements with importers of U.S. grains would serve to undergird the goal of maintaining and expanding exports of grain and their products. The agreements would contain the following considerations: (*a*) each importer would be required to purchase a minimum prespecified volume of grain each year from the United States (plus some growth factor), and each importer would be guaranteed this amount at the threshold price whenever the export levy was in effect; (*b*) each importer would be required to build and operate a grain reserve stock program in which the stock levels are related to, or determined by, the nation's average volume of grain imports; (*c*) the importer would be required to release and acquire stocks in its reserve program in accordance with the same rules as those employed in the management of the U.S. reserve stock; and (*d*) the last two conditions are waived for low income, developing countries.

The establishment of a system of bilateral agreement emanating from the United States should accomplish three important things: (*a*) expand and regularize the export of grains from the United States, (*b*) assure importers of grain from the United States of their regular supply in years of world shortages, and (*c*) greatly increase the probability of holding the world price of grain within the agreed upon price stabilization range.

As a consequence of the above set of results, the probability of the variable export levy becoming operational is greatly reduced. This consequence fits into the overall design of this proposal. The variable export levy is not viewed as a revenue generator; it is viewed as a control mechanism for stabilizing the domestic price of grain. And when the world price of grain is stabilized within an acceptable range by the operations of a system of coordinated national grain reserve programs, the variable export levy need not come into operation.

Global Allocations

It is conceivable that exports to nonagreement countries would be sufficiently brisk in the first part of a marketing year, at prices below the threshold price, that domestic demand plus the bilateral agreement commitments in the latter part of the marketing year would push the domestic market price above the threshold price. The operation of an effective system of national grain reserve programs in conjunction with the variable export levy makes such a development unlikely, but it remains a possibility. Thus, it is proposed here the United States establish a global allocation for each major category of grain each marketing year that is equal to the expected domestic demand for each category of grain at the stabilization target price, plus the export quantities fixed in the bilateral agreements plus whatever food aid commitments that the government may have made. Private exporters would be free to export grain to any nonagreement country, with or without the export levy in operation, to that point where the global allocation was being infringed upon. At this point, sales to nonagreement countries would cease. The remaining supplies would be sufficient to meet bilateral agreement and domestic commitments.

Domestic Grain Reserves

To fulfill the U.S. obligation of assured supplies to signatories, the CCC, it is proposed, should be re

quired to purchase and maintain an adequate level of stocks labeled as grain reserves. A study by Cochrane and Danin on maintaining world prices in a plus 10% and minus 5% of trend band, required reserve stocks that averaged 50 to 75 million tons over the 1975–85 period. With this proposal, such a large stock level is not required to help stabilize U.S. grain prices since the link between the U.S. grain price and the world grain price is broken whenever the world price exceeds the threshold price of U.S. grains. However, in this proposal the United States is committed to providing minimum supplies to signatories and is committed to providing grain supplies during a global shortage, and therefore, the United States must maintain an adequate level of reserves to meet these obligations. If the United States does not follow this course, then its role of a dependable supplier of grains is in jeopardy.

Currently, domestic grain stocks are composed of farmer-held reserves, CCC stocks, and private stocks. At present, these stocks are not directly accessible to serve as part of a reserve system. The reasons are as follows: First, farmers are not required to market the farmer-held reserves when the Secretary of Agriculture calls the loan. The producer pays only the loan, and hence, can speculate with these stocks. Second, there are no well-defined rules regarding the marketing of CCC stocks. At present, the resale price is set at not less than a certain percentage of loan. Third, the majority of stocks are private and the government has no direct control over the marketing of these stocks. Therefore, these stocks should become more accessible so that they can be considered part of the reserve system. This could be accomplished by changing the rules governing the release of farmer-held reserves and by expanding the role of the CCC with regard to purchasing and selling grain in the market.

Implications of the Proposal

The consequences of this proposal are different from the effects of an export embargo, which also protects domestic agriculture. An export embargo has a surprise element, whereas the operation of the levy system and the global allocation scheme is known and obvious to all. Also, since the operation of the levy and the global allocation scheme is plainly incorporated into agricultural legislation, this proposal minimizes many of the moral and political problems associated with controlling exports in periods of extreme food shortage.

When world price is above threshold, then signatory importers are at a relative advantage to nonsignatory importers. This relative advantage is the difference in prices paid for grain imports. An outcome of this proposal is that if enough importers comply with the agreements, then free-riders benefit from the stability of these agreements. However, the free-rider is at a disadvantage if and when there is a global production shortage because these importers are not guaranteed supplies in accordance with the bilateral agreements and the global allocation. Thus, these nations are forced to adjust to changing world conditions. Consequently, the onus is shifted from the United States to the rest of the world to stabilize world grain markets. The easiest course would be for them to sign bilateral agreements with the United States or other major exporters (e.g., Canada, Australia). Thus, it may be to the advantage of all grain exporters to consort on elements of this proposal.

The distinct advantage of this proposal is that there does not have to be an international agreement on decision rules, such as when prices or quantities trigger acquisition or release of stocks, and who should carry these stocks. A multilateral agreement on these regulations is virtually impossible (Cochrane). Instead, the United States takes the initiative in setting price stabilization ranges and formulating grain operating rules. These rules would govern the size of country reserve stocks, the acquisition and release of stocks based on world prices, and the provision of food aid. Agreement to these operating rules would be given by participating countries in return for guaranteed supplies and purchase price limits.

Export levies are a form of export tax and the latter are considered unconstitutional. Article 1, Section 9, Clause 5 of the U.S. Constitution states that "No Tax or Duty shall be laid on Articles Exported from any State" U.S. Code, Annotated). Where there was a proper exercise by Congress of its power to regulate commerce, it has been held that the export clause did not limit such power (*American Law Reports*). The case of *Moon (Appellent)* v. *Freeman* (*Secretary of Agriculture*) *et al.*, exemplifies the point. Moon contended that the purchase of export wheat marketing certificates (under the Agricultural Act of 1964) was analogous to an export tax and prohibited by the Constitution. "Overruling Moon's contention, the court interpreted the Statute (Agriculture Act of 1964) as an exercise by Congress of its power to regulate commerce under the Constitution, which is not to be limited by the constitutional prohibition against taxation of exports. The court stated that the purpose of the statute was to induce producers to comply with crop controls and to regulate the price of wheat reaching both the domestic and foreign markets" (*American Law Reports*). Export controls which have a similar effect as export taxes on prices and amounts exported are not prohibited by the Consitution. Under the auspices of the Export Administration Act of 1969 the Congress declared that it is "the policy of the United States to use export controls to the extent necessary to protect the domestic economy from the excessive drain of scarce materials and to reduce the inflationary impact of abnormal foreign demand" (U.S. Code Service). The purpose of the export levy in this proposal is to regulate domestic price and to reduce the inflationary impact of abnormal foreign demand.

The ruling on the case of *Moon* v. *Freeman* and the legality of export controls to protect domestic interests serves as a precedent for arguing that the export levies in this proposal should not be considered unconstitutional.

Another effect of this proposal is that if the United States is in a situation where the export tax must be applied then the resulting world price would not convey the same exact information as when world grain price is in the stabilized band (i.e., between the loan and threshold levels). The world price in this situation would be artificially higher than before, but other supplemental information, such as the value of the export tax, world stock levels, and the percentage of world imports that are under the umbrella of the bilateral agreements, could be used by the grain market. When world price is above threshold, then world price plus the above data should reflect as much information as price by itself when world price is below threshold.

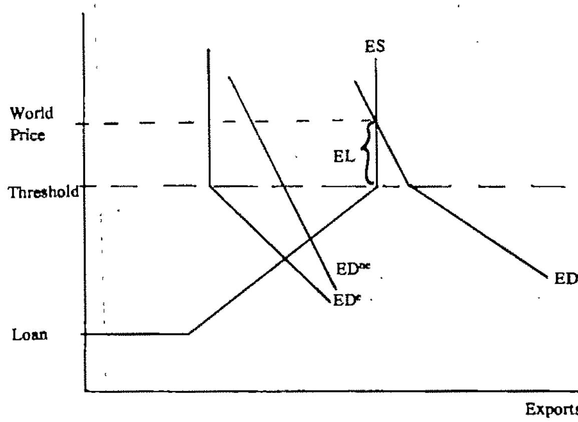
World price is a function of the proportion of imports valued at the threshold price when world price is above the threshold. Specifically, the larger the percentage of imports that are sold at threshold, the higher the world price. The structure of the world grain market in this situation is illustrated in figure 2. In this figure, the U.S. export supply function (ES) and the import demand function for complying countries (ED^c) are unresponsive to world price levels above threshold. Only the net import demand for noncomplying countries (ED^{nc}) is responsive to world price above the threshold level. The elasticity of the total net import demand function can be represented by

$$E_{ED}t = E_{ED}c\ E_Pc\ S + E_{ED}nc\ E_Pnc\ (1 - S),$$

where $S = \frac{ED^c}{ED^t}$ is the complying import share; $E_{ED}i$ are import demand elasticities with respect to world price, $i = t,\ c,\ nc;$ and E_Pj are price transmission elasticities, $j = c,\ nc$. This elasticity is used to show the effect of import share on world price. To do this, assume that U.S. exports had to be curtailed by 5% in one period to maintain domestic prices at threshold, and restrict $E_Pc = 0$ since above threshold a signatory's domestic price is insulated from the world price. Hence,

$$\%\Delta P = \frac{5}{E_{ED}nc\ E_Pnc\ (1 - S)},$$

where $\%\Delta P$ is the percentage change in world price. Thus, holding everything else constant, world price increases as the import share to complying countries increases. As a consequence of this result, the cost associated with not complying increases dramatically as more nations sign the bilateral agreements. Thus, if the United States can induce a few large importers to enter into this agreement, then it would be to the advantage of all other importers to become signatories. Therefore,



Note: Where ES is U.S. export function; ED^c is import demand function for compliers; ED^{nc} is net import demand for the rest of the world; ED^t is total net import demand; and EL is export levy.

Figure 2. An export levy, import shares, and world price

the free-rider problem mentioned above should be minimal.

This proposal is supplementary to the provisions of the 1977 Food and Agriculture Act and the proposals should be implemented such that the instrument of this proposal do not dominate the 1977 Act. Most particularly, the threshold levels for grain should be set above equilibrium values to enable price to perform its functions around the equilibrium value. This draws attention to what is the intermediate to long-run equilibrium level of price, and this should be on the research agenda before the proposal is implemented.

Another important implication of this proposal for future research consideration is a concern that domestic price may automatically tend toward threshold if this proposal is implemented. This policy proposal is directed at the marketing and trade level of the grain sector and this sector may respond to the policy by removing supplies from the market until price moves to the threshold level. This will not occur because this increase in price cannot be realized on the removed supplies, for if these supplies were added to marketable supplies then price would drop to its former level. The trade's main function is to provide services, such as transportation and brokering, and hence the removal of supplies to enhance price does not benefit the grain trade. If this is not the case, then the trade would be engaged currently in this type of activity.

This proposal involves an export levy and a global allocation scheme for grains. For operational purposes this requires an institution to oversee and coordinate these instruments. A research question that follows concerns the desired structure of the grain trade. The grain trade need not be nationalized, because the CCC could administer the allocation system and export levy system when they need to be operational. This does require closer

communication between the grain trade and the CCC for example.

A final research consideration involves the empirical question of what size of reserve stocks is optimal for the United States if this proposal is implemented. Because the link between the U.S. price and world price is broken above threshold, the stock level should be smaller than indicated by the Cochrane and Danin study, for example. The separation of working stocks and reserve stocks, and their substitutability under different structures should also be investigated for effective operation of this proposal.

Concluding Comments

The viability of United States food and agriculture is dependent on exports to the world grain market. Insulating policies by importers and variable import demands contribute to the instability of the world grain market. As a means to reduce the American grain sector's vulnerability to this instability, this paper proposes that American food and agriculture policy should move in the direction of insulating domestic food and agriculture from world instability and at the same time maintain its position as a dependable supplier of world grains. Existing programs which currently insulate U.S. agriculture from weak foreign demand are included in the proposal. Export levies in conjunction with the global allocation system are proposed because they can insulate domestic agriculture from transitory surges in foreign demand. As a result, domestic price is stabilized between the loan rate and the threshold price, and the American grain sector is open to the world market when world price is in the price stabilization band.

Also included in the proposal are bilateral agreements which require importers to maintain reserve programs. These agreements and the global allocation system ensure complying importers their import requirements at, or below, the threshold price. The bilateral agreements augment stability in the world grain market by requiring importers to increase their reserve stock holdings as world price declines and to decrease these holdings as world price increases. American reserve grain stocks would operate in the same manner. The export levy would rarely be operational because the deployment of reserve stocks held under the bilateral agreements, the domestic reserve stock held by the United States, and the global allocation scheme in all likelihood would hold the world price within the defined price stabilization band.

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References

Brandow, G. E. "Grain Reserves and the U.S. Economy: A Policy Perspective." *Analysis of Grain Reserves.* Washington, D.C.: U.S. Department of Agriculture ERS-634, Aug. 1976.

Bressler, R. G., and R. A. King. *Markets, Prices, and International Trade.* New York: John Wiley & Sons, 1970.

Cochrane, W. W. "Reserve Stocks: An International Perspective." Presented at a conference on Food and Agricultural Policy Issues. Spring Hill Center, Wayzata, Minn., 11 Mar. 1978.

Cochrane, W. W., and Y. Danin. *Reserve Stocks Grain Models, The World and the United States, 1975–85.* University of Minnesota Agr. Exp. Sta. Tech. Bull. 305, 1976.

Cochrane, W. W., and M. Ryan. *American Farm Policy 1948–1973.* Minneapolis: University of Minnesota Press, 1976.

Johnson, D. Gale. *The Soviet Impact on World Grain Trade: An Executive Summary.* British-North American Committee, May 1977.

Johnson, P. R., T. Grennes, and M. Thursby. "Devaluation, Foreign Trade Controls, and Domestic Wheat Prices." *Amer. J. Agr. Econ.* 59(1977):619–27.

Nelson, G. L. "International Food Policy Issues." *The Lessons of Wage and Price Controls—The Food Sector,* eds. J. T. Dunlop and K. J. Fedor. Boston: Harvard University Press, 1977.

Spitze, R. G. "The Food and Agriculture Act of 1977: Issues and Decisions." *Amer. J. Agr. Econ.* 60(1978):225–35.

United States Code Service. *War and National Defense,* FCA ed., Title 50, Appendix, Sec. 2402, 1978.

U.S. Department of Agriculture. *Commodity Program Provision under the Food and Agriculture Act of 1977.* ERS Agr. Econ. Rep. No. 389, Washington, D.C., Oct. 1977.

U.S. Government. "Constitution of the United States." *United States Code Annotated,* Article 1, Section 9, Clause 5.

"What Amounts to Prohibited Federal Tax on Exports within Article 1, Section 9, Clause 5 of the Federal Constitution." *American Law Reports: Federal Cases and Annotations* 3(1970):550–61.

Producer-Consumer Trade-Offs in Export Cartels: The Wheat Cartel Case

Colin Carter, Nancy Gallini, and Andrew Schmitz

Since the formation of the Organization of Petroleum Exporting Countries (OPEC), several models of cartel-competitive fringe markets for an exhaustible resource have been developed. Derivations of Nash-Cournot equilibrium price paths under such a regime and insightful behavioral descriptions of limit pricing by monopolists facing potential competition have enriched the literature concerning this market structure (Salant and Gilbert and Goldman). In addition, the gains to producers from cartelization in the oil, copper, and bauxite industries have been derived empirically (Pindyck).

Largely in reaction to OPEC, numerous discussions have focused on an important but different commodity than those mentioned above. Several proposals (supported by many producers and consumers) have been put forth to form a cartel in wheat among the major exporters: the United States, Canada, Australia, and Argentina.[1] If such a cartel were organized, which group or groups have the most to gain? The above studies on exhaustible resources do not distinguish between producer and consumer effects in the exporting countries largely because domestic demand for this type of good is small relative to the total amount exported. In oil, for example, there is little need to distinguish between a producer export cartel, which maximizes producer returns, and a government cartel which maximizes the welfare of all groups since the solutions would be very similar. However, this is not necessarily the case for other commodities where domestic demand is an important component of market structure (e.g., in wheat the domestic demand is large relative to total wheat exports).[2]

The purpose of this paper is to consider a market in which the commodity in question has a relatively large domestic demand component and to demonstrate that a sharp distinction has to be made between a producer export cartel and a government export cartel. This paper shows (abstracting from implementation issues raised by Caves, Pindyck, and McCalla and Schmitz) that producers actually may lose from a government cartel. The conditions under which this can happen are derived theoretically. The model is then applied to the world wheat economy; and, interestingly, the empirical results suggest that there is a strong possibility that producers would, in fact, lose from a government wheat cartel if there are decreasing returns in production unless compensated by a tax on consumers. This result raises several important policy issues.

Government and Producer Cartels

The model in figure 1 gives the maximum gains from a government export cartel under the initial condition of free trade, perfect competition in the production and consumption sectors, and no retaliation on the part of importers. The demand and supply curves for the exporter of good X are D_C and S_C while, for the importer, the corresponding schedules are D_D and S_D. The excess demand curve for the importer is ED, and the excess supply curve for the exporter is ES. The free-trade price is P_F. The government cartel solution for the exporting country is computed by determining where the ES schedule crosses the marginal revenue curve (MR) pertaining to ED. The price in the importing country becomes P_C (for both consumers and producers), and the price in the exporting country for both producers and consumers becomes P_D. The tax revenue is *abcd*.

Unless consumers are effectively taxed by producers, the latter could well lose from the optimal government export tax shown in figure 1. Their alternative is the formation of a producer export cartel with the objective of maximizing producer welfare (recall that the government export cartel maximized the welfare of society). Under the producer cartel arrangement, the producers would always gain because the cartel would discriminate against domestic as well as foreign consumers. The producer cartel takes surplus from both the importer and the domestic consumer, whereas the gov-

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[1] For instance, H.R. 3042 was introduced by Congressman Weaver on 15 March 1972 (Terpstra). The bill proposed the creation of a National Grain Board to yield the highest possible prices in foreign markets for American agricultural producers.

[2] In the 1977–78 crop year, for example, the consumption of wheat in the major exporting nations was approximately 34.7 million metric tons (mmt), while exports were 56.4 mmt and production was 89.6 mmt.

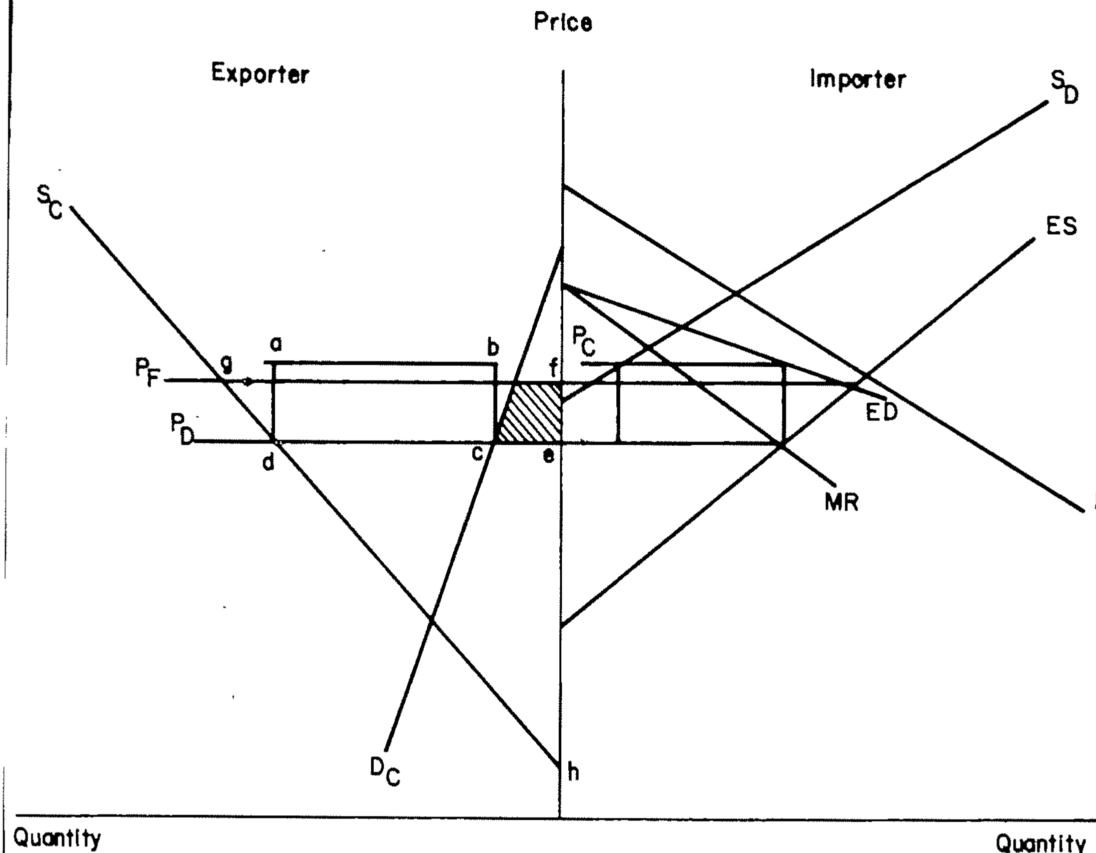

Figure 1. Optimal export cartel: with domestic demand

ernment cartel (discussed above) takes economic surplus only from the importing country.

Figure 2 represents the case where demand is absent in the exporting country. The free-trade price is P_F. Under a cartel solution, producer prices in the exporting country drop to P_D, but they increase to P_C in the importing contry. Clearly, the producer cartel solution and the government cartel solution are identical; and producers would always gain from a cartel. Their net gain in rents is $P_c abd - efg$. It is now clear why for wheat, unlike oil, a distinction has to be made between a government export cartel and a producer export cartel. In wheat, the schedule, D_C, is relatively much more important than in oil.

In the model in figure 1, the government cartel solution maximizes the welfare of both producers and consumers jointly. As a result, the government export cartel solution has to result, in the absence of retaliation, in a net welfare gain for the exporting country. However, what about specific groups in the exporting country? From figure 1, clearly the consumers gain from an export cartel by an amount of the crosshatched area. But what about producers? There is a loss to producers in the form of economic rent of *defg* and a gain in tax revenue of *abcd* (assuming that the tax revenue is given to producers).[3] Interestingly, producers can actually lose from the cartel. In figure 1, the loss in economic rent exceeds the gain in tax revenue. This will not always be the case, however, as will be shown later. Note that the reason the producers can lose from a government export cartel while society as a whole can gain is that consumers gain in the exporting country as a result of the cartel.

Producer Welfare and Government Cartels

In the following section, the conditions are derived under which producers are made worse off by a government cartel. The following notation is employed: P_C (cartel price to importing countries), P_D (domestic price in exporting countries under the cartel), P_F (free-trade price), and Q_i^j (output corresponding to the jth price on the ith curve), where $j = D$ (domestic price), F (free-trade price), or C (cartel price) and $i = ES$ (excess supply), ED (ex-

[3] In the case where the revenue is given to producers, acreage controls, or whatever will be needed to restrict output since the true producer price is no longer P_D if the tax revenue is viewed as a return on output.

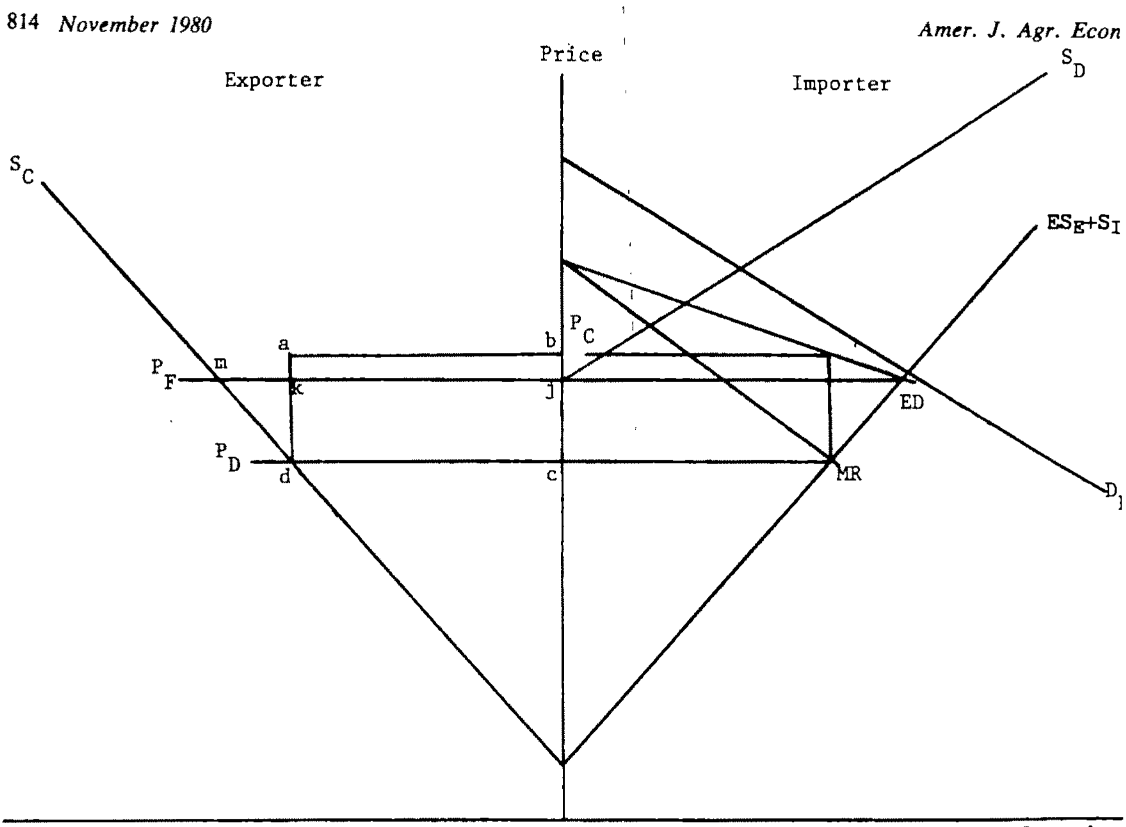

Figure 2. Optimal export cartel: without domestic demand

cess demand), S (supply of the exporting country), or D (demand of the exporting country). For linear excess supply and demand curves,[4] the net benefits to the producers in the exporting countries from a government cartel can be written as

$$(1)\quad B_P = (P_C - P_F)Q_{ES}^D - (P_F - P_D)\left[Q_D^D + \frac{1}{2}(Q_S^F - Q_S^D)\right].$$

The domestic price resulting from the government cartel is expressed in terms of the cartel price and the elasticity of excess demand at P_C—ϵ_{ED}^C—by the well-known relationship,

$$(2)\qquad P_D = P_C\left(1 - \frac{1}{\epsilon_{ED}^C}\right).$$

Then the producer benefits are negative when moving from a free-trade position to a government-formed cartel market structure if

$$(3)\qquad \frac{1}{\epsilon_{ED}^C}[(Q_{ES}^D - Q_{ES}^F) - (Q_D^F + Q_D^D)] < \frac{P_F - P_C}{P_C}(Q_S^F + Q_S^D).$$

To gain more insight into the inequality in (3), the excess demand and supply prices are specified, respectively, as

$$(4)\qquad P = \alpha - \beta Q_{ED},$$

$$(5)\qquad P = \gamma + \delta Q_{ES},$$

where α, β, and $\delta > 0$.

Expressions for the equilibrium prices and quantities under free trade and cartelization are determined in terms of the parameters in (4) and (5) and substituted into expression (3). The free-trade price, P_F, is the result of equating Q_{ES} with Q_{ED}. That is,

$$(6)\qquad P_F = \frac{\alpha\delta + \beta\gamma}{\beta + \delta}.$$

The cartel price in the importing countries (inclusive of the export tax) is that price for which the corresponding quantity of excess demand equals the quantity of excess supply at P_D, where P_D is defined in (2). That is, P_C is given by

$$(7)\qquad P_C = \frac{\alpha\delta + \beta\gamma}{\delta + \beta\,(1 - /\epsilon_{ED}^C)}.$$

Substituting $(P_F - P_C)/P_C$ for $-\beta/(\beta + \delta)\epsilon_{ED}^C$ and deriving the expressions for Q_{ES}^F and Q_{ES}^D obtains

$$(8)\qquad \frac{\beta\,(\alpha - \gamma)}{(\delta + \beta)} - \delta\,(Q_D^F + Q_D^D) < 0.$$

Inequality (8) suggests the impact of domestic demand on the change in producers' rents due to a change in market structure. If domestic demand equals zero at both the free-trade and cartel prices, the producers are always made better off from a

[4] Linear demand and supply curves are used to correspond to the empirical model in Section 3.

government cartel. Because it is assumed that the producers receive the entire export tax revenue, this corresponds to the single-market monopoly solution. However, if there is a domestic demand, there is a loss in producer surplus in the domestic market. The imposition of the export tax by the government (i.e., the government export cartel solution) has the effect of shifting the excess demand faced by the producers downward by the amount of the tax, thus resulting in a constrained competitive equilibrium price for the commodity less than that under free trade.

Further insight into the condition in (8) can be gained by formulating it for the exogenous parameters. Let $P = a - bq$ be the domestic demand for the commodity, then the condition can be rewritten as

$$(9)\quad \frac{\beta(\alpha-\gamma)}{(\delta+\beta)} - \frac{\delta}{b}\left(2a - \frac{\alpha\delta+\beta\gamma}{\beta+\delta} - \frac{\delta\alpha+2\beta\gamma}{\delta+2\beta}\right) < 0.$$

Algebraic manipulation transforms the left-hand side of (9) into a quadratic in β and is given by:

$$(10)\quad \beta^2[2b(\alpha-\gamma) - 4\delta(a-\gamma)] + \beta[b\delta(\alpha-\gamma) - 3\delta^2(2a-\gamma-\alpha)] - 2\delta^3(a-\alpha) < 0.$$

Let $F(\beta, \cdot)$ describe the function on the left-hand side of the inequality in (10) for given values of all the parameters except β. Differentiation of $F(\beta, \cdot)$ reveals that the function has a minimum at β^*, where

$$(11)\quad \beta^* \gtreqless 0 \quad \text{if} \quad b \lesseqgtr \frac{3\delta(2a-\gamma-\alpha)}{(\alpha-\gamma)}$$

$$b > \frac{2\delta(a-\gamma)}{(\alpha-\gamma)}$$

and a maximum at

$$\beta^* < 0 \quad \text{if} \quad b < \frac{2\delta(a-\gamma)}{(\alpha-\gamma)}.$$

Furthermore, if the intercept of the domestic demand exceeds that of the excess demand curve (i.e., $a > \alpha$), the value of the function evaluated at $\beta = 0$ is less than zero. The solid curves in figure 3A and 3B, respectively, illustrate the cases in which $F(\beta,\cdot)$ has a maximum and $b = \underline{b}$ where $\underline{b} < 2\delta(a-\gamma)/(\alpha-\gamma)$, and one of the cases in which the function has a minimum and $b = \bar{b}$ where $2\delta(\alpha-\gamma)/(\alpha-\gamma) < \bar{b} < 3\delta(2a-\gamma-\alpha)/(\alpha-\gamma)$. Note that only the positive orthants in figure 3A and 3B are of interest since a downward sloping demand curve has been assumed. Thus, if the slope of the domestic demand, b, is small relative to the slope of the excess supply, δ, the producers will always lose from a cartel (fig. 3A); if the domestic demand is fairly steep, there will be a critical β, β_1 in figure 3B above which there is a welfare gain to producers of the commodity.

As the value of a changes, there will be a shift and change in the functions shown in figure 3 by the dotted line. In particular, if $a = \alpha$, $F(\beta, \cdot)$ is linear; and it can be shown that the condition under which producers lose from a cartel is

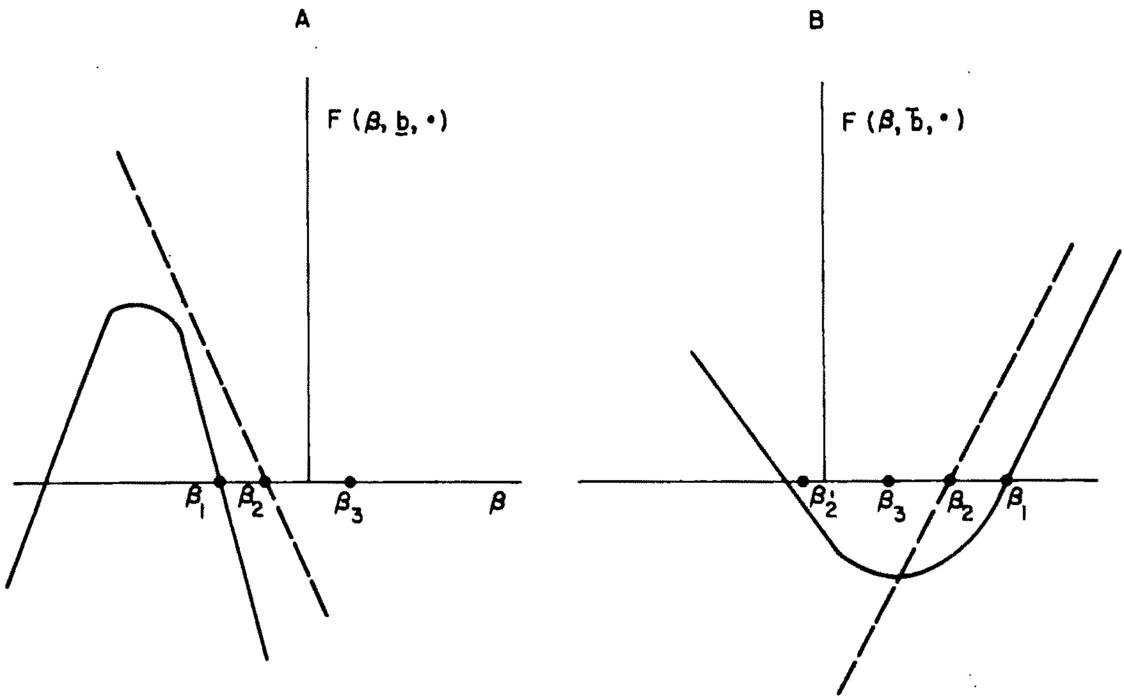

Figure 3. Critical values of excess demand slope

$$\beta < \frac{\delta\,(3\delta - b)}{2\,(b - 2\delta)} = \beta_2$$

for $2\delta < b < 3\delta$. Evaluating $F(\beta, \cdot)$ at β_2 in (12), given a is some value greater than α, indicates that the shift in the function due to a change in a places β_2 to the right of β_1 in figure 3A and to the left of β_1 in figure 3B. Note that producers lose from the cartel in the case of a relatively flat domestic demand (fig. 3A). However, unlike the previous case, if $b > 3\delta$, the critical value for β, β'_2, above which the producers are made better off from the cartel, lies in the negative orthant (fig. 3B). Thus, the producers should favor the development of the cartel regardless of the values of the other parameters. Finally, if $a < \alpha$, it can be shown that the critical β, β_3 for figure 3B lies further to the left of β_2 but still in the positive orthant. However, for the case of the small slope of domestic demand described in figure 3A, producers are better off from the cartel formation for $\beta \in (0, \beta_3)$.

These results are quite intuitive since they suggest that, as the intercept of the domestic demand falls below that of the excess demand curve (that is, as the domestic demand becomes more insignificant), the range of values which the slope of the excess demand curve can take on to insure a gain to producers under the cartel market structure gets larger. Also, as the slope of the demand gets larger, holding all else constant, the producers will more likely benefit from the cartel.

To summarize the results:

Result 1. If there is no domestic demand, producers always gain.

Result 2. If there is a domestic demand, then producers

(a) always gain, if $b > 3\delta\,(2a - \gamma - \alpha)/(\alpha - \gamma)$ and $a \leq \alpha$. If $a > \alpha$, there exists a β_1 above which producers gain from the cartel;

(b) always lose if $b < 2\delta\,(a - \gamma)/(\alpha - \gamma)$ and $a \geq \alpha$. If $a < \alpha$, there exists a β_3, below which producers will gain from the cartel;

(c) will gain if $2\delta\,(a - \gamma)/(\alpha - \gamma) < b < 3\delta\,(2a - \gamma - \alpha)/(\alpha - \gamma)$ and the slope of the excess demand is greater than some critical $\beta > 0$ which is a function of a, α, γ.

Empirical Results: The Wheat Cartel Case

The highly aggregate market model, described in figure 1, has never been estimated empirically for the wheat market, at least not to the authors' knowledge. Less aggregate empirical studies do exist, however. For the purpose of this paper, the most relevant of these is the one by Rojko, Urban, and Naive (hereinafter referred to as the ERS study).

The ERS study divides the world into twenty-two regions, and it has estimated linear supply and demand equations for wheat in each region. Average data for 1964–66 provide the base for the model. The parameters of the supply and demand equations are not all econometrically estimated. Some of the parameters are synthesized from economic theory and statistical findings.

From the estimates of the ERS study, aggregate supply and demand functions were computed for the major wheat exporters and importers. The aggregate supply and demand curves were obtained by a horizontal summation of the countries' individual supply and demand curves. Because of time constraints, these estimates are likely as good as one can realistically derive for the world wheat market given the purpose at hand which is only to show that producers may actually lose from a government export cartel. It must also be recognized that it is very difficult to "statistically fit" supply and demand functions for the world wheat market.

The export sector in our aggregation process is made up of the United States, Canada, Australia and Argentina (these countries account for over 80% of world wheat exports). The importing bloc includes the United Kingdom, Japan, western and eastern Europe, South America, Asia, etc. (ERS study).

By substituting 1978–79 average data for the coarse grains and rice price and quantity variables, the intercept terms of the ERS supply and demand equations were adjusted and expressed as functions of own-price and quantity only. The adjusted aggregate equations serve as the basis for the empirical estimates of the welfare effects of a wheat cartel in table 1. The annual net trade of the Soviet Union and China is treated exogenously by increasing the intercept of the importers' excess demand function for wheat by 15 million metric tons (mmt) per annum to approximately correspond to 1980 net imports.[5]

The aggregate equations of the wheat model are

Exporters:

$$Q_{Sd_t} = 90{,}757.4 + 380.4\,P_t \tag{13}$$

$$Q_{Dd_t} = 45{,}285.0 - 54.4\,P_t \tag{14}$$

$$Q_{ESd_t} = 45{,}472.4 + 434.8\,P_t \tag{15}$$

Importers:

$$Q_{Sf_t} = 165{,}912.9 + 288.9\,P_t \tag{16}$$

$$Q_{Df_t} = 355{,}676.1 - 395.9\,P_t \tag{17}$$

$$Q_{EDf_t} = 189{,}763.2 - 684.8\,P_t, \tag{18}$$

where Q_{Sd_t} is total annual supply of wheat in the exporting bloc (× 1,000 tonnes), Q_{Dd_t} is total annual demand for wheat in the exporting bloc (× 1,000 tonnes), Q_{ESd_t} is total annual excess supply of wheat in the exporting bloc (× 1,000 tonnes), Q_{Sf_t} is total annual supply of wheat in the importing bloc

[5] A 10-year (1965–75) average of net imports of wheat by the USSR and China is nearly 10 million tons per annum; for exact figures, see International Wheat Council.

Table 1. Welfare Effects of the Formation of a Wheat Cartel by the Major Exporters, 1980

Major Exporters	Welfare Effects[a]	Major Importers	Welfare Effects
	(U.S. $mill.)		(U.S. $mill.)
1. Gain in consumers' surplus	5,361	1. Loss in consumers' surplus	25,202
2. Loss in producers' surplus	17,049	2. Gain in producers' surplus	17,780
3. Export tax revenue	16,003	3. Net loss (1 minus 2)	7,422
4. Net gain (1 plus 3 minus 2)	4,315		
5. Loss to producers including tax revenue (2 minus 3)	1,046		

Source: Own estimations.
[a] The values are estimated for a single time period only.

($\times$ 1,000 tonnes), Q_{Df_t} is total annual demand for wheat in the importing bloc ($\times$ 1,000 tonnes), Q_{EDf_t} is total annual excess demand for wheat in the importing bloc ($\times$ 1,000 tonnes), and P_t is price of wheat (dollars per tonne) in 1979 dollars.

Table 1 gives the welfare gains and losses resulting from an optimal government-controlled cartel. The estimates are based on equations (13) through (18). Interpretation of the estimates of gains and losses presented in table 1 should be done with some caution. The empirical results rest on the assumption that the market was in competitive equilibrium when the ERS parameter estimates were made and, more important, that the formation of a wheat cartel is done *vis à vis* an initial competitive situation.

The estimates show that, even if producers receive the entire export tax revenue, they are worse off with a government wheat cartel. Their loss is estimated at roughly $1 billion per year. The welfare gain accruing to consumers in the exporting nations is $5.4 billion per annum. This interesting empirical result makes it clear that consumers in the exporting countries have the most to gain from an optimal export tax because the domestic price falls substantially under such an arrangement.

In relating the empirical findings to the specifications in the previous section, the following suggestions are offered as the major determinants of the net loss accruing to the wheat producers in the domestic market:

The estimated quantity demanded domestically [from (13) through (18)] at the free-trade and cartel-constrained prices is 30.9 mmt and 38.2 mmt, respectively, while the estimated domestic supplies at these prices are 191.2 mmt and 140.3 mmt. Thus, domestic demand comprises a significant 16% and 27% of the total domestic supply under the two market structures.

For the estimated equations (13) through (18), $a = 832$, $\alpha = 277$, $b = .02$, $2\delta\ (a - \gamma)/(\alpha - \gamma) = .01$, and $3\delta\ (2a - \gamma - \alpha)/(\alpha - \gamma) = .03$. Therefore, $a > \alpha$ and b lies in the interval bounded by .01 and .03.

Relating these estimates to expression (10) leads to the conclusion that the critical β below which producers will lose from the formation of a cartel is .0028. Because the estimated slope of the excess demand function is .0015, there is a loss to producers.

Thus, the relatively large demand for wheat by domestic consumers and the relatively flat importers' excess demand are the indicators of a possible loss to producers from a government-formed cartel.

Conclusions

Theoretically, it has been shown that the formation of a government export cartel, in which the government takes into account the welfare of producers and consumers, does not necessarily result in a welfare gain to producers unless consumers are taxed. In the world wheat economy, the results show that the producers in the exporting countries would lose from such an arrangement in the wheat market. However, it should be kept firmly in mind that the results are compared to a situation of free trade, and no retaliation is assumed on the part of importers. Both of these assumptions should be relaxed in future research. Concerning the free-trade assumption, this may be highly restrictive in view of the optimal tariff thesis recently proposed by Carter and Schmitz. In this case, a cartel threat may result in the EEC moving to freer trade. Also, if, for example—in reaction to the cartel price—technological change occurs, the cartel may create disincentives in the form of limit pricing. It should be noted that, while the producers in the importing country always gain from the cartel arrangement, it is conceivable that they may improve their position by increasing their production at home, even at the expense of a lower cartel price.

A policy issue raised by the analysis (not clearly pointed out previously) is that, even though governments, producers, and many consumers in the major wheat exporting countries seem to support some type of wheat cartel arrangement, there may be a conflict of interest among these groups once specific proposals are examined in detail. The results of this paper show that, if a government cartel is formed, consumers have the most to gain and

producers in the exporting countries may, in fact, lose unless appropriate redistribution policies are introduced. The issue of current redistribution policies that now exist in the wheat versus nonagricultural sectors is not addressed in this paper.

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References

Carter, C., and A. Schmitz. "Import Tariffs and Price Formation in the World Wheat Market." *Amer. J. Agr. Econ.* 61(1979):517–22.

Caves, R. E. *Organization, Scale, and Performance in the Grain Trading Industry.* Disc. Pap. No. 546, Harvard Institute of Economic Research, 1977.

Gilbert, R. J., and S. M. Goldman. "Potential Competition and the Monopoly Pricing of an Exhaustible Resource." *J. Econ. Theory* 17(1978):319–31.

International Wheat Council. *World Wheat Statistics.* London: Bradleys, Reading, and London, 1975, an subsequent annual issues.

McCalla, A. F., and A. Schmitz. "The Welfare Effects c Imperfections in International Trade: The Case c Grain Cartels." Paper presented at the Food Re search Institute, Stanford University, Mar. 1979.

Pindyck, R. "Gains to Producers from Cartelization of a Exhaustible Resource." *Rev. Econ. and Statis* 60(1978):238–51.

Rojko, A. S., F. S. Urban, and J. J. Naive. *World De mand Prospects for Grain in 1980 with Emphasis o Trade by Less Developed Countries.* Washingtor D.C.: U.S. Department of Agriculture, For. Agı Econ. Rep. 75, 1971.

Salant, S. W. "Nash-Cournot Equilibrium: The Case c the Cartel." *J. Polit. Econ.* 84(1976):1079–95.

Terpstra, A. E. "An Analysis of Possible Cartel and Ba ter Arrangements to Influence the Price and Avai ability of Wheat on the International Market." Wasl ington, D.C.: Congressional Res. Pap., Library c Congress, May 1979.

Import Tariffs and Price Formation in the World Wheat Market: Comment

Thomas Grennes and Paul R. Johnson

One of the well-known results of orthodox trade theory concerns the ability of exporters and importers to take advantage of less than perfectly elastic demand and supply functions. It is possible to tax imports or exports so that foreign suppliers or foreign demanders pay some of the tax. In this way, it is possible that the national income of a buyer or seller nation can be increased relative to a free-trade position. In fact, with sufficient information on supply and demand functions, one can find the tax that maximizes welfare, the so-called optimum tariff.

Most tariffs are not of this nature. Typically, tariffs have been imposed for revenue purposes or for protection of domestic producers of a good. For the United States, where export taxes are unconstitutional, the opposite case of an optimum export levy is even less discussed. (For an exception, see Johnson 1964). Since motivations are not easily analyzed, one must go to the market evidence for inferences about putative monopoly or monopsony behavior. Recently Carter and Schmitz (CS) have done this for the international wheat market. They test the hypothesis that for certain periods two of the major importers of wheat, Japan and the European Economic Community (EC), have wielded market power in such a way that their tariffs are close to optimum. In our judgment this analysis seems to gloss over some relevant information, and hence it could be misleading. Our concern is not with the proposition that Japan and the EC may individually or collectively be large enough importers to affect the price. Rather, we are concerned with the conclusion that the EC and Japanese import tariffs on wheat, in practice, have not only been welfare increasing (for EC and Japan) but have been close to optimal.

The Carter-Schmitz Optimum Tariff

The standard formula for deriving the optimal tariff in a partial equilibrium setting for a particular product is that the percentage tariff be equal to $1/E$, where E is the elasticity of excess supply that the country in question faces. CS do not present estimates for elasticities. They deal with linear demand and supply functions, and the reader can obtain elasticity estimates by reading off numbers from their figure 2. Our calculations based on figure 2 lead to the following estimates: (*a*) the elasticity of supply of the major exporters at the equilibrium price of \$147/ton (their estimate) is .54; (*b*) the elasticity of excess supply facing the two importers is .75; (*c*) the elasticity of the total supply function facing the importers (excess supply plus supply in the importing countries) is .49.[1]

The implied optimum tariff (by $1/E$) associated with the elasticity in (*c*) is 2.04. This estimate is roughly consistent with some other arithmetic they produce. The market price (in 1964–66 dollars according to figure 2) associated with the optimum tariff is \$198/ton. The price to the exporters from this price and the tariff is \$72. The implied tariff, then, is \$126. This tariff is approximately 180% of \$70. The implied elasticity of excess supply is then 1/1.80 or .55. So, we conclude that CS are calculating optima from a supply elasticity in the neighborhood of .5. Such an elasticity implies a great deal of market power.

The optimum tariff is a function of the elasticity of supply of imports facing a nation. The import supply elasticity can be expressed in terms of the supply and demand elasticities in the rest of the world:

$$E = \frac{S}{M}\epsilon_w - \frac{D}{M}\eta_w,$$

where S is supply in the rest of the world, D is demand in the rest of the world, M is imports, ϵ_w and η_w are the respective supply and demand elasticities in the rest of the world. Underlying this expression is the assumption that price changes occurring in the importing country are transmitted to the exporting country. If, instead, suppliers of imports in the rest of the world are insulated from price changes in the importing country, their supplies will be less responsive than this expression indicates (see Bredahl, Meyers, Collins). In the extreme case of complete insulation,[2] the observed

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[1] This elasticity is taken at point A in figure 2 of CS. It is not clear from the diagram how or why domestic supply was added to excess supply to calculate the tariff. We are trying to generate the numbers that are only implicit in their article. The correct elasticity to use would seem to be the excess supply elasticity. The implied optimum tariff is then 150%, still larger than observed in the EC.

[2] When insulation occurs, it is necessary to distinguish between prices in the importing country (P^*) and prices in the exporting

import supply elasticity will be zero regardless of the values of ϵ_w and η_w. This problem of insulating trade policies has been empirically important for grain, and it has been discussed extensively in this *Journal* (D. G. Johnson; P. Johnson, Grennes, Thursby; Shei and Thompson; Josling; and Zwart and Meilke). The issue of the variability of trade barriers is important, but at this point let us follow CS and ignore it. The problem of insulation is addressed separately below.

Consider the optimum tariff level implied by conventional values of supply and demand parameters. Let the elasticity of supply in the rest of the world lie between +.2 and +.5 and the demand elasticity between −.1 and −.3. We have calculated weights for *S/M* and *D/M* for four periods. The first is a four-year average 1965–69, and the others are the crop years ending 1972, 1976, and 1977. Following CS, the USSR and China are omitted, although this biases the import elasticity downward and the optimum tariff upward.

Weights of 16 and 15 and extreme values of the above elasticities result in an implied value of the import supply elasticity of +4.7 to +12.5. The associated optimal tariff should lie between 8% and 21%. The discrepancy between these numbers and the CS optimum tariff is large, indeed. We do not claim great precision for these import supply elasticities; but if they are in error, they are likely to understate the true elasticities. Japan and the EEC have taken less than 20% of world wheat imports, and this leaves a large residual market to respond to price fluctuations. For example in the crop year 1976, India imported more wheat than Japan. Since we do not expect complete agreement on the elasticity estimates, we offer additional evidence on the world wheat market concerning the CS thesis.

The Actual EEC Tariff and the Carter-Schmitz Optimum Tariff

The optimum tariff for the CS model is approximately 180%. The most damaging evidence facing the model is that the actual tariff has been far below this level. Of course, the actual levy varies continuously, but for the period 1966–73, the CS optimum tariff, as they recognize, was more than twice as high as the actual EEC tariff.[3] Even when one excludes the years most embarrassing to the mode (1973–76), the actual tariff rates ranged from 68%–87%. From the middle of 1973 to the end of 1974 the EEC wheat levy was zero. Japan does not impose an explicit tariff, but an implicit rate can b calculated from the difference between the sellin and buying prices of the Japan Food Agency. I 1973–74 this implicit wheat tariff was negative.

The Variable Levy As an Optimum Tariff

The salient characteristic of the EEC grain tariff i its continuous variability, but CS do not discuss thi feature. Because the optimum tariff rate is equal t the inverse of the import supply elasticity, the EE levy is optimal only if it moves inversely with ϵ_w The levy has systematically deviated from that pattern, and evidence can be found in the recent literature on insulating trade policies. When foreign grai suppliers prevent price changes from being transmitted to their domestic economies (transmissio elasticities decline), ϵ_w is diminished and the optimal EEC tariff should increase. In 1973–74, man of the major grain-trading countries carried out insulating trade policies. Instead of raising the tarif to exploit a less elastic import supply, the EE reduced the levy all the way to zero. The collectiv monopsony power of EEC countries was used t worsen the terms of trade of the customs union The nature of the variability of the EEC grain lev guarantees its suboptimality.

U.S. Export Policy and USSR–China Import Policy

CS deal with two periods, one prior to 1972–74 an one subsequent to those years. Their price data an diagrams refer to the earlier period. They observ an export price in the neighborhood of $72/ton. Thi price is approximately one-half of their estimate equilibrium price and is attributed to importer exercising their monopsony power. An alternativ explanation of low world prices is the export pro motion policies of major sellers. Both the Unite States and Canada used foreign markets to try t reduce wheat inventories that accumulated as a re sult of domestic intervention policy. At one poin Public Law 480 programs were involved in 85% o U.S. wheat exports, and before 1972 subsidies wer also paid on commercial exports. Thus even if al importers behaved competitively, there have bee important price-depressing forces coming from ex port suppliers.

A discussion of monopsony in the world whea market is incomplete without considering the rol

country (P). The elasticity of supply of imports with respect to price in importing country is

$$E^* = \eta_{P^*P}\left(\frac{S}{M}\epsilon_w - \frac{D}{M}\eta_w\right),$$

where $\eta_{P^*P} = \dfrac{dP^*}{dP}\dfrac{P}{P^*}$ is the transmission elasticity with respect to prices in the exporting and importing (P) countries. With complete insulation $\eta_{P^*P} = 0$ and $E^* = 0$ for any ϵ_w and η_w.

[3] The dollar tariff is the same for all varieties of wheat, but because wheat is a differentiated product, the tariff rate depends on the variety and price chosen. The rough figures reported above refer to U.S. no. 2 Hard Winter and 13.5% at Rotterdam a reported by the U.S. Department of Agriculture in *Foreign Agriculture* before 1976.

of the USSR and China. Both have abandoned earlier attempts at self-sufficiency, and in the 1970s, they have been major wheat importers. Indeed, in the last three crop years both the USSR and China imported more wheat than either Japan or Western Europe (U.S. Department of Agriculture 1979, p. 21). An interesting empirical question is whether the price-depressing effect of EEC-Japan protectionism has been greater than the price-increasing effect of Soviet-China trade expansion. To the extent that tariffs in the EEC and Japan permitted buyers in those countries to obtain wheat at lower prices than they otherwise would, these same consumer benefits were shared by Soviet and Chinese buyers. This free-rider problem is one of the main reasons why most historical monopsonies have broken down.

Changes in Market Power

CS present their monopsony model as an alternative to the earlier view of the world wheat market as an oligopoly (see Alaouze, Watson, Sturgess; McCalla). One of the puzzling aspects of the oligopoly model is how frequently competitive price wars break out. Producer country market power seems to appear and disappear without a warning. CS assert that the wheat market has usually been a buyers market, but they concede that the monopsonistic importers lost power in the high price years of the 1970s. It is curious the way this alleged market power shifts so frequently from one group to another. Finding the welfare-maximizing tariff must be difficult for the interested governments.

Monopsony, Oligopoly, and the Theory of Regulation

The CS monopsony model and the oligopoly model of the world wheat market are incompatible with each other; but they share the same implicit theory of government regulation.[4] Both views represent the public interest theory of regulation (see Stigler; Posner; Abrams and Settle) which implies that governments choose policies that will maximize national income. In this context the monopsony view says that governments adjust tariff rates so as to maximize national income rather than domestic producer income. The oligopoly view says that exports will be restricted to achieve the highest national income even if domestic producer income suffers. According to the alternative economic theory of regulation those private groups most affected by trade policy will try to influence policy so as to promote their private interests even if national income falls. In this context, the economic theory implies that wheat policy would be determined by the interests of domestic wheat producers of the trading countries. Because producer interests sometimes conflict with rules necessary to achieve a cohesive national oligopoly or monopsony, the collusive arrangements break down. The economic theory of regulation rejects both monopsony and oligopoly models as useful representations of world wheat markets. Because there is much evidence that wheat policy in the EEC, and the United States is more strongly influenced by wheat producers than wheat consumers, we find the economic theory more convincing than the public interest theory. In spite of tariffs the world wheat market is not simply a buyers market, and in spite of attempted collusion by exporters the market is not simply a sellers market. As in most other markets it is the interaction of both supply and demand that determines wheat prices. A proper analysis of wheat trade cannot ignore barriers or export controls, but these important institutions can be and have been incorporated into competitive trade models.

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[4] CS state (p. 517) that both views of the market may be compatible. However, all of the calculations in their paper are based on competitive import supply curves which are irrelevant if the suppliers are oligopolists. Similarly, Alaouze, Watson, and Sturgess confronted their triopolists with competitive demand curves (p. 181). One could represent the wheat market as a bilateral monopoly but this has not been done in the literature, and it presents problems for the notion of an optimum tariff.

References

Abrams, Burton A., and Russell F. Settle. "The Economic Theory of Regulation and Public Financing of Presidential Elections." *J. Polit. Econ.* 86(1978): 245–57.

Alaouze, C. M., A. S. Watson, and N. H. Sturgess. "Oligopoly Pricing in the World Wheat Market." *Amer. J. Agr. Econ.* 60(1978):173–85.

Bredahl, Maury E., William H. Meyers, and Keith J. Collins. "The Elasticity of Foreign Demand for U.S. Agricultural Products: The Importance of the Price Transmission Elasticity." *Amer. J. Agr. Econ.* 61(1979):58–63.

Carter, C., and Andrew Schmitz. "Import Tariffs and Price Formation in the World Wheat Market." *Amer. J. Agr. Econ.* 61(1979):517–22.

Johnson, D. Gale. "World Agriculture, Commodity Policy, and Price Variability." *Amer. J. Agr. Econ.* 57(1975):823–28.

Johnson, Paul R. "The Social Cost of the Tobacco Program." *J. Farm Econ.* 47(1964):242–55.

Johnson, Paul R., Thomas Grennes, and Marie Thursby. "Devaluation, Foreign Trade Controls, and Domestic Wheat Prices." *Amer. J. Agr. Econ.* 59(1977):619–627.

Import Tariffs and Price Formation in the World Wheat Market: Reply

Colin Carter and Andrew Schmitz

The purpose of our paper was to put forth and empirically test the alternate viewpoint to the generally accepted notion that price formation in the world wheat market is determined largely by the major exporters. We emphasized that the market power on the part of importers of wheat is perhaps greater than the power attributed to exporters by previous researchers. This hypothesis was motivated by the observation that the major importers of wheat (especially Japan and the European Economic Community [EEC]) practice trade restriction. This phenomenon is true for other agricultural commodities as well (e.g., feed grains, beef, and dairy products); and perhaps our hypothesis would also receive strong empirical support for some of these other markets.

Grennes and Johnson (GJ) suggest that our analysis could be misleading to the reader. Our conclusion that the EEC and Japanese trade barriers have enhanced their own economic welfare is challenged. GJ imply these import barriers are used for noneconomic reasons. They also express concern over our findings that the import tariffs (or equivalent quotas) are optimal. Nowhere in our paper do we argue that the import tariffs and quotas are exactly optimal. We argue that these barriers seem to approach optimality. As GJ rightly suggest, an optimal tariff would be next to impossible to calculate at each moment in time largely because of the stochastic nature of supply of agricultural products.

The analysis of optimum tariffs in our paper draws on the graphical exposition in figure 1. The optimum tariff solution can easily be shown algebraically as well. Suppose we have a one commodity-two country world or a two good-two country world with a numeraire commodity. Let $p_s(q)$ be the (inverse) excess supply curve of the commodity which faces the importing country and assume $p'_s(q) > 0$. To maximize national welfare, the importing nation equates its excess demand price, $p_d(q)$, to the marginal cost of importing the commodity. Hence, the optimizing condition is

$$(1) \qquad p_d(q^*) = p_s(q^*) + p'_s(q^*)q^*, \text{ or}$$

$$(2) \qquad p_d(q^*) = p_s(q^*)\left(1 + \frac{1}{\epsilon_s}\right),$$

where ϵ_s is the elasticity of excess supply and is > 0.

Condition (1) states that the marginal benefit of an additional unit of the imported good $p_d(q^*)$ is equal to the marginal cost of obtaining it. However, the exporting nation is paid less for the commodity than the marginal benefit that it confers on the importing nation. The wedge driven between the price in the importing nation, $p_d(q^*)$, and the price in the exporting nation, $p_s(q^*)$, can be defined as the optimal import tariff (τ). Defining τ in percentage terms, we find

$$(3) \qquad \tau = \frac{p_d(q^*) - p_s(q^*)}{p_s(q^*)} = \frac{1}{\epsilon_s}.$$

This condition states that the percentage change in the import tariff rate is inversely related to the elasticity of excess supply. It is obvious from (3) that, as $\epsilon_s \rightarrow \infty$, the behavior of the importer approaches free trade.

GJ use condition (3) to infer the elasticities associated with our linear supply and demand functions. They conclude that our implied estimate of ϵ_s is in the neighborhood of .5 and is far too low. Their smallest estimate of ϵ_s is at least ten times this magnitude. This discrepancy arises for one major reason. Our calculations are made correctly because we take into account all major importers, including the centrally planned economies; GJ's calculations are for the EEC and Japan only. This is the reason they estimate the large weights of sixteen and fifteen for S/M and D/M, respectively. In our original paper we argued that Japan and the EEC may be acting as price leaders in setting a near optimal import tariff (for the group of importers) and thus depressing the world price of wheat. The other major importers (e.g., USSR, China, India, Brazil, Korea, Pakistan, Egypt, etc.) also benefit from the lowered world price and, in addition, may be using tariffs and quotas to their advantage. This is somewhat analogous to the benefit accruing to fringe oil suppliers (e.g., Mexico and Canada) from the export tax placed on oil by OPEC.

The 1973–75 period is not as embarrassing to our simple model as GJ suggest. They mention that the EEC levy was near zero in the 1973–74 period. The levies were low during this period as the EEC was not in a position to exert power in the market during the "commodity boom" at the time. We recognized in our paper that this was an atypical period. Bar-

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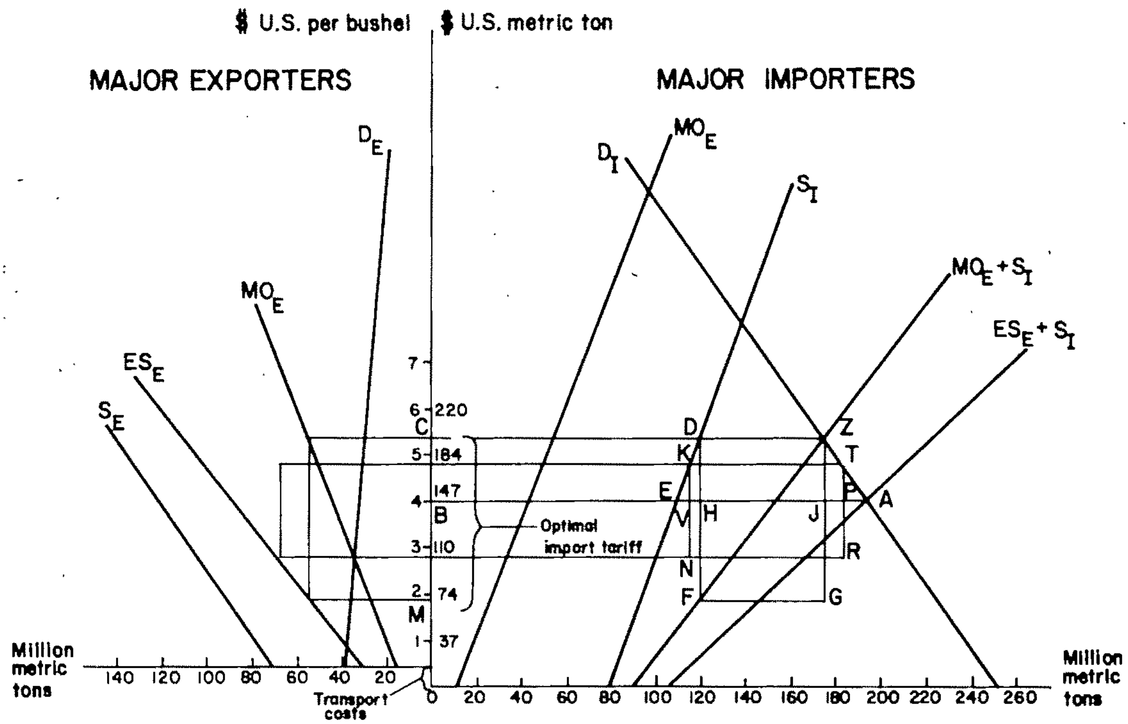

Figure 1. Empirical estimate of the optimal import tariff solution (1964–66 prices)

ring periodical exceptions, our model seeks to explain the general phenomena in the market of importers exerting power. In this context, our model includes a tariff which has a probability distribution associated with it.

GJ suggest that the EEC tariff has been historically below our optimal calculated level of 180%. This fact we cannot deny. The Atlantic Council of the United States has projected the probable level of the tariff-equivalent of the EEC variable levy on wheat, during normal times, to equilibrate at 120%. Cline et al. estimate the tariff equivalent of the Japanese quota to be approximately 145%.

Japan is a much more important importer of wheat than is the EEC, and GJ have much less to say about the Japanese import barriers except for a passing comment that their implicit tariff on wheat was negative during the commodity boom period. The statistics in table 1 of Carter and Schmitz do not support this comment even during the period of high world prices. In any event, the restrictive policies of Japan seem to fit our hypothesis better than do those of the EEC.

In this discussion it is important to recognize that the tariff need not be optimal to be welfare improving. This can be seen clearly in figure 1. Suppose that the importers set a tariff that is somewhat less than the optimal *CM* and is equal to *KN*. This suboptimal tariff is still welfare increasing for the importers *vis-à-vis* free trade. The net gain is equal to the area *NRPV* − (*KEV* and *TAP*).

GJ argue that the EEC tariff rates are normally 68% to 87%. We have drawn the tariff *KN* in figure 1 to correspond roughly to an import tariff of 70%. Even though this lower tariff is not optimal, it is still beneficial to the importing nations. The tariff revenue associated with *KN* is estimated to be approximately $5.2 billion. Consumers in the importing country would lose an estimated $6.0 billion and producers would gain $3.3 billion under this tariff. The net gain to the importing nations, therefore, would be an estimated $2.5 billion (1964–66 dollars). The requirement that the import tariff be optimal is not, therefore, crucial for the major results of our analysis to hold. The wheat importing nations benefit from restricted trade and the magnitude of the benefits depend on how close their restrictive policies are to being optimal.

Earlier price wars in the wheat market are coined "competitive" by GJ. However, McCalla has shown that price wars do not imply a competitive market. GJ discount the relevance of the studies by Carter and Schmitz; Alaouze, Watson and Sturgess; McCalla; and Taplin because they reject the notion that governments choose policies with the aim of maximizing national welfare. We fail to see the trade-off between import tariffs (quotas) and high domestic producer incomes in the EEC and Japan. Quite the contrary, we believe that the producers in these countries support trade barriers and so may consumers because governments can use the tariff revenues to offset the negative consumption effect of the tariff. If one could assume that the economic theory of regulation applies (as GJ do), then it is puzzling why consumers in Japan and the EEC do not lobby for freer trade in agricul-

tural commodities and why the governments do not give in to their demands. The consumers obviously have more to lose from restricted trade than the producers have to gain if tariffs are welfare decreasing in an aggregate sense. But if they are not, consumers may favor tariffs depending on how the tariff revenue is distributed.

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References

Alaouze, Chris M., A. S. Watson, and N. H. Sturgess. "Oligopoly Pricing in the World Wheat Market." *Amer. J. Agr. Econ.* 60(1978):173–85.

Atlantic Council of the United States. *GATT Plus: A Proposal for Trade Reform.* Washington, D.C., 1975.

Carter, Colin, and Andrew Schmitz. "Import Tariffs and Price Formation in the World Wheat Market." *Amer. J. Agr. Econ.* 61(1979):517–22.

Cline, W. R., N. Kawanabe, T. O. M. Kronsjo, and T. Williams. *Trade Negotiations in the Tokyo Round: A Quantitative Assessment.* Washington, D.C.: The Brookings Institution, 1978.

McCalla, Alex. "A Duopoly Model of World Wheat Pricing." *J. Farm Econ.* 48(1966):711–27.

Taplin, J. M. "Demand in the World Wheat Market and the Export Policies of the United States, Canada and Australia." Ph.D. thesis, Cornell University, 1969.

The Structure and Changes of Technology in Prewar Japanese Agriculture: Comment

Timothy L. Hunt

In a recent issue of this *Journal*, Nghiep presents an explanation of the structure and changes of technology in Japanese agriculture, 1903–38, using a translog cost-function approach. The interesting and unique feature of Nghiep's work is the application of a distributed lag scheme (Nerlove) to each of the derived cost share equations. The article relates the desired cost shares (S^*) and actual cost shares (S) for factor input i at time period t as,

$$(1) \qquad (S_{it} - S_{it-1}) = \alpha_i(S^*_{it} - S_{it-1}),$$

where Nghiep shows that the adjustment parameter is a constant across the input cost shares, i.e., $\alpha_i = \alpha$, because the real or desired cost shares must add up to one in the translog case. That leads directly to the input share equations,

$$(2) \quad S_{it} = \alpha\gamma_i + \Sigma_j\alpha\gamma_{ij}\ln P_j + \alpha\gamma_{it}\ln T + (1 - \alpha)S_{it-1}.$$

Nghiep's development and application of (2), a dynamic version of the translog cost function, is a valuable contribution. However, there are two major deficiencies.

First, no economic rationale or empirical evidence in support of the assumed lag structure, which implies that farmers adjust all factor inputs—land, labor, machinery, fertilizer, and other—to their desired cost shares at the same rate, α, is offered. Nghiep's proof that $\alpha_i = \alpha$ in the translog case is correct, but the plausibility of economic agents behaving as postulated in the model is not discussed. Even Nerlove has examined the possibility of an equality in the lag parameter between factor inputs and dismissed it as "grossly unreasonable" (p. 141).

Nevertheless, given Nghiep's assumed lag structure, it is possible to evaluate the restriction empirically. Individual R^2 and t-values are of little help because the system of equations in (2) is simultaneous with constraints across equations in which the assumed lag structure itself involves an additional constraint. Therefore, the parameter estimate on the lagged value of the dependent variable, and through it the assumed lag structure, must be evaluated as part of a simultaneous system.

It is disappointing that Nghiep did not carry out a statistical test of his assumed lag structure. First, the null hypothesis of $\alpha = 1$ versus the alternative hypothesis of $\alpha_i = \alpha$ can be tested, in which case failure to reject the null hypothesis means there is no overall support for the distributed lag scheme in (1), i.e., the translog cost function is static. Second, the null hypothesis of $\alpha_i = \alpha$ versus the alternative hypothesis of $\alpha_i \neq \alpha$ can be tested, in which case failure to reject the null hypothesis implies support for Nghiep's model specification. This second test is possible because, in general, the actual sample estimates of the adjustment parameter will not be the same across the input cost shares even though the model specification implies such equality. For more detailed exposition of these tests, see Christensen, Jorgenson, and Lau, and others.

The second deficiency of the article is that the translog functional form itself may be inappropriate in this case. In general, due to its quadratic nature, the translog functional form will not satisfy the conditions for a well-behaved (regular) cost function globally; it is a local approximation only. However, for most applied econometrics situations, this is not a hindrance to the utilization of translog because it is possible to test the estimated translog cost function for regularity in the observed range of input prices. In brief, the translog cost function is monotonic if the fitted cost shares are positive at each data point; it is concave if the matrix of estimated Allen elasticities is negative semidefinite at each data point; and it is symmetric if the restrictions $\gamma_{ij} = \gamma_{ji}$ cannot be rejected.

Keeping in mind that the regularity conditions are minimal conditions implied by economic theory and that the regularity tests are standard in the translog cost literature including Binswanger (1974b), Berndt and Wood, and Halvorsen, it is unfortunate that these tests were not carried out (or at least not reported) and instead the restraints implied by regularity were simply imposed on the estimating model.

Even so, there is some indication that the cost function estimated by Nghiep is not regular because two of the five direct price elasticities are positive, specifically those for land and machinery. Nghiep, however, suggests support for these results by arguing that an aggregate cost function for agriculture need not be well-behaved, or that farmers "utilize their labor force to develop new land and to produce farm implements in slack seasons when the prices of these items rose" (p. 691). While the existence of aggregation problems in macro studies is well-known, many such studies have found the

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regularity conditions satisfied using a translog framework including Binswanger (1974a) for U.S. agriculture and Kako for Japanese rice production. Furthermore, the possibility of upward-sloping factor demand curves appears remote and without support in the literature.

The fundamental problem with both of Nghiep's suggestions, however, is that they involve a denial of the very theory on which his estimating model is based. Specifically, Nghiep's suggestions imply either that a meaningful aggregate cost function does not exist, or that if one exists, it is not regular. However, if the true production and cost structure is not regular, then the Shephard duality theorem cannot be used to relate the first derivative of the translog cost function with respect to the log of the factor prices to the cost shares, because regularity is a condition of the theorem itself as indicated by Shephard (pp. 169–71) and amplified in Diewert (p. 112). Furthermore, it is inappropriate to impose the constraints suggested by regularity on estimating equations of a cost structure which itself is not regular. Allen (pp. 503–09) clearly pointed out that imposition of regularity on a cost structure restrains the constant output price (E_{ij}) and Allen (σ_{ij}) elasticities such that $\Sigma_j E_{ij} = \Sigma_j S^*{}_j \sigma_{ij} = 0$. Thus, if the estimated own-price elasticity is positive, indicating irregularity, then some or all of the cross elasticities must be biased because the zero sum requirement remains.

There is an alternative explanation of the lack of regularity in the estimated model; namely, the problem lies within the estimated function only. For example, the domain of the sample may be such that a local approximation of the underlying cost function is not meaningful, or the estimating model itself may be misspecified, possibly because of a left-out exogenous policy variable or because of the imposition of a highly restrictive (and untested) lag structure. Regardless, the estimates remain biased and of little value because now the lack of regularity in the estimated model is indicative of a failure to estimate the true, regular cost function.

Thus, Nghiep's suggestions indicating the true cost function need not be regular are misguided, particularly in the translog case, because the estimating model itself is derived on the basis of regularity. The alternative is to ascribe the lack of regularity to the estimated function only. In both cases, however, the parameter estimates and derived elasticities are biased and therefore of little value in explaining the structure and changes of technology in prewar Japanese agriculture.

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References

Allen, R. G. D. *Mathematical Analysis for Economists.* New York: Macmillan Co., 1938.

Berndt, E. R., and D. O. Wood. "Technology and the Derived Demand for Energy." *Rev. Econ. and Statist.* 57(1975):259–68.

Binswanger, H. P. "Cost Function Approach to the Measurement of Elasticities of Factor Demand and Elasticities of Substitution." *Amer. J. Agr. Econ.* 56(1974):377–86.

———. "The Measurement of Technical Change Biases with Many Factors of Production." *Amer. Econ. Rev.* 64(1974b):964–76.

Christensen, L. R., D. W. Jorgenson, and L. J. Lau. "Transcendental Logarithmic Production Frontiers." *Rev. Econ. and Statist.* 55(1973):28–45.

Diewert, W. E. "Applications of Duality Theory." *Frontiers of Quantitative Economics,* vol. 11, ed. M. D. Intriligator and D. A. Kendrick, pp. 106–71. Amsterdam: North-Holland Publishing Co., 1974.

Halvorsen, R. "Energy Substitution in U.S. Manufacturing." *Rev. Econ. and Statist.* 59(1977):381–88.

Kako, T. "Decomposition Analysis of Derived Demand for Factor Inputs: The Case of Rice Production in Japan." *Amer. J. Agr. Econ.* 60(1978):628–35.

Nerlove, M. *Estimation and Identification of Cobb-Douglas Production Function.* Chicago: Rand-McNally & Co., 1965.

Nghiep, L. T. "The Structure and Changes of Technology in Prewar Japanese Agriculture." *Amer. J. Agr. Econ.* 61(1979):687–93.

Shephard, Ronald W. *Theory of Cost and Production Functions.* Princeton, N.J.: Princeton University Press, 1970.

The Structure and Changes of Technology in Prewar Japanese Agriculture: Reply

Le Thanh Nghiep

Hunt's first comment is on the assumption that the share adjustment parameters are equal across inputs and across time. This assumption, according to the commentator, is intuitively unrealistic and needs empirical justification. In what follows I will use some numerical examples to show that (*a*) the across-input equality of the adjustment parameters, as proved in my paper, is an unavoidable identity, and that (*b*) the across-time equality of the parameters is a plausible assumption.

Consider the following three distributed lag schemes:

$$(1) \qquad (S_{it} - S_{it-1}) = \alpha(S^*_{it} - S_{it-1}),$$

$$(2) \qquad (X_{it} - X_{it-1}) = \beta_i(X^*_{it} - X_{it-1}),$$

$$(3) \qquad (X_{it} - X_{it-1}) = \frac{X^*_i - X_{i0}}{n_i},$$

where $i = 1, 2$; S stands for factor share, X for input quantity, and $*$ indicates the corresponding desirable level. Equation (1) is the adjustment scheme used in my paper (hereafter, NG adjustment). Equation (2) is the well-known Nerlovian adjustment scheme (hereafter, NE adjustment). Equation (3) presents a lag scheme in which the adjustment path of input quantity is a straight line (hereafter, SI adjustment). Table 1 and table 2 present the corre sponding share adjustment parameters compute from an NE-adjustment case with $\beta_1 = 0.5$, and $\beta_2 =$ 0.2, and an SL-adjustment case with $n_1 = 2$, and $n_2 =$ 5. It is observed that the resulting adjustment pa rameters are always identical across inputs how ever different are the input-adjustment parameters The resulting share adjustment parameters, how ever, tend to decrease in case of NE adjustmen (table 1) and increase in case of SL adjustmen (table 2). Thus, the NG adjustment is not consisten with both NE and SL schemes. However, fron these computation results we can conjecture tha the corresponding input adjustment path falls ir somewhere between those of NE and SL schemes Therefore, the assumed across-time equality o share adjustment parameters is not implausible.

Hunt's second comment well depicts the prob lems of my paper. I do not have much to say excep the following three points, for the readers to rightl understand my paper. First, the paper hypothesize and empirically showed that in the period 1900–4(the Japanese agricultural sector was locked int extremely narrow regions of factor substitution and large parts of changes in the input levels o production factors were due to biased technica changes. It is not whether a substitution or demanc

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Table 1. Derived Share-Adjustment Parameters: Nerlovian Distributed Lag of Input Quantit ($\beta_1 = .5, \beta_2 = .2$)

		$t = 0$	$t = 1$	$t = 2$	$t = 3$
Price	Factor One		1	1	1
	Factor Two		2	2	2
Desirable quantity	Factor One	10	20	20	20
	Factor Two	15	10	10	10
Desirable share	Factor One		.5	.5	.5
	Factor Two		.5	.5	.5
Actual quantity	Factor One	10	10	15	17.5
	Factor Two	15	15	14	13.2
Actual share	Factor One		.25	.348837	.398633
	Factor Two		.75	.651163	.601367
Share adjustment parameter	Factor One			$\frac{.348837 - .25}{.5 - .25} = .395$	$\frac{.398633 - .348837}{.5 - .348837} = .329$
	Factor Two			$\frac{.651163 - .75}{.5 - .75} = .395$	$\frac{.601367 - .651163}{.5 - .651163} = .329$

Table 2. Derived Share Adjustment Parameters: Straight-Line Adjustment of Input Quantity ($n_1 = 2$, $n_2 = 5$)

		$t = 0$	$t = 1$	$t = 2$	$t = 3$
Price	Factor One		1	1	1
	Factor Two		2	2	2
Desirable quantity	Factor One	10	20	20	
	Factor Two	15	10	10	10
Desirable share	Factor One		.5	.5	.5
	Factor Two		.5	.5	.5
Actual quantity	Factor One	10	10	15	20
	Factor Two	15	15	14	13
Actual share	Factor One		.25	.348837	.434783
	Factor Two		.75	.651163	.565217
Share adjustment parameter	Factor One			$\frac{.348837 - .25}{.5 - .25} = .395$	$\frac{.434783 - .348837}{.5 - .348837} = .569$
	Factor Two			$\frac{.651163 - .75}{.5 - .75} = .395$	$\frac{.565217 - .651163}{.5 - .651163} = .569$

elasticity is 0.1 or −0.1. The problem is that most of elasticities are not significantly different from zero. Second, as irregularity arose for land and machinery, the two rather fixed factors, it is likely that the apparent irregularity was due to inappropriate treatment of effective prices and farmers' decision making with respect to investment in fixed factors. My quotation that farmers might use their labor force in slack seasons to develop new land and to produce farm implements when the prices of these items rose was on this line.[1] Third, from various farm surveys and direct interviews with farmers in contemporary developing countries, the rational behavior of farmers with respect to price changes has achieved universal recognition. However, this does not necessarily indicate that those estimated functions which satisfy the regularity conditions are free from fault. By empirical studies we economists are searching for farmers' true but unknown technical structure, and all our estimated results are more or less subject to errors. My view is that the appraisal and discussion of an empirical study should not be focussed only on its estimated results. Instead, the appraisal and discussion should be made on the relationships between these results and the setting of hypotheses, the analysis framework, and the data treatment.

Finally, I appreciate Hunt's detailed comments. Although I cannot agree with him entirely, I believe that his comments brought about insights into the related issues.

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[1] Although Hunt mentioned that Japanese studies proved that prewar Japanese farmers responded to normal incentives, I am still not aware of any research on land and machinery markets in the concerned period.

Inflation and Farm Tractor Replacement in the U.S.: A Simulation Model: Comment

R. B. Bartholomew

In a recent article in this *Journal,* Bates, Rayner, and Custance argued for the incorporation of inflation in replacement decisions and stated that the effect of inflation is to increase the optimal replacement age of farm tractors (p. 333). While I agree with the authors on the justifications of treating inflation in replacement decisions, I believe that under one condition their conclusion is incorrect and the effect of inflation could well be to lower the optimal replacement age. This occurs when the discount rate declines as inflation increases.

Inflation and Taxation

The effect of inflation in Bates, Rayner and Custance's model is to increase the optimal replacement age, because (*a*) tax credits for depreciation are based on historic costs, and in real terms are thus lower under inflation; (*b*) tax credits are lagged and in real terms are lower under inflation; (*c*) the difference between resale price and unexpired depreciation is likely to increase dramatically during periods of inflation. As this difference is taxable when the item is sold, the effect of this increase in tax payable is to increase the after-tax cost of the new tractor in real terms.

All of the above considerations are valid; and, other things being equal, the net effect is an increase in the optimal replacement age of the tractor. But, under inflation, do other things remain equal, particularly the discount rate?

Discount Rate

As the authors treat all cost items in real terms, i.e., the effect of inflation has been removed, the discount rate they use is correctly an after-tax real discount rate which they call r. Given a real after-tax discount r, there must exist a nominal pre-tax discount rate which I have called R. The relationship between r and R is as follows:

$$r = \frac{R\,(1 - T) - \theta}{1 + \theta},$$

where r is real after-tax discount rate, T is tax rate, θ is inflation rate, and R is nominal pre-tax discount rate. Table 1 lists R for different values of θ and r, assuming a tax rate of 25%.

Using a real after-tax discount rate of 5% implies nominal pre-tax discount rates of 6.7%, 13.7%, and 20.7% for rates of inflation of 0%, 5%, and 10%, respectively. If these nominal discount rates do not apply, then assuming a constant real discount rate after tax of 5% in our example is not valid.

Inflation and the Discount Rate

The discount rate has been viewed in different ways, e.g., the "cost of capital," a growth of reinvestment rate or in the limiting case where the farmer/investor did not have any better alternative use for his equity than to lend it to himself or pay off existing debts, as the cost of borrowed money to finance the particular asset acquisition. Whichever view is adopted, it is clear that the rate of inflation will affect the value of the nominal discount rate and thereby the real discount rate. If we look at bank lending rates it is apparent that while the lending rate is higher under inflation, the real rate of interest has not kept pace with inflation. Table 2 shows the interest rate on trading bank overdrafts for Australia for the period 1969–76.

In the limiting case where the real discount rate after tax is simply the cost of borrowed money (after tax) adjusted for inflation, then this rate is certainly not invariant to the rate of inflation, as shown in table 2. In only half the years is the real discount rate before tax positive, while in only two years out of eight is the real discount rate after tax positive. While the bank lending rate may be viewed as the minimum nominal discount rate, the general conclusion surely holds that the relevant nominal discount rate need not increase sufficiently during periods of inflation to maintain a constant real discount rate after tax.

Table 3 is taken from Bates (p. 333) and shows that for a particular tax rate and inflation rate, the lower the real after-tax discount rate, the earlier the optimum replacement age. If one accepts the view that under periods of continuing inflation the real after-tax discount rate is not constant and is lower than in the absence of inflation, then there exists an incentive to earlier not later replacement.

Whether this incentive can be realized will depend on such factors as the earnings of the re-

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Table 1 Nominal Discount Rate, Real Discount Rate, and Rate of Inflation (%)

Real Discount Rate after Tax (r)[a]	Nominal Discount Rate before Tax (R) Inflation Rate 0	5	10
1	1.3	8.3	14.8
3	4.0	10.9	17.7
5	6.7	13.7	20.7
10	13.3	20.7	28.0

[a] Tax rate of 25¢ on the dollar.

placement machine *vis à vis* its annual capital cost and the overall financial situation on the farm business, but this is a rather separate aspect of the replacement decision.

Table 2. Interest Rate and Inflation (%)

Year	Nominal or Market Rate	Inflation Rate	'Real Rate of Interest'	Real Rate (after Tax)[a]
1969	7.75	3.4	4.2	2.3
1970	8.25	4.9	3.2	1.2
1971	8.25	7.0	1.2	−0.8
1972	7.75	5.8	1.8	−0.1
1973	7.75	13.7	−5.2	−6.9
1974	9.50	16.5	−6.0	−8.1
1975	11.50	13.1	−1.4	−4.0
1976	11.50	13.9	−2.1	−4.7

[a] Tax rate of 25¢ on the dollar. Interest rate is trading bank overdraft rate on overdrafts less than $50,000.

Table 3. Optimal Replacement Age, Discount Rate and Inflation

Tax Rate (%)	Discount Rate (%)	Inflation = 0	Inflation 5% per Annum	Inflation 10% per Annum
25	1	8.9	9.5	10.2
25	3	10.5	11.4	12.5
25	5	13.4	13.9	14.0
25	10	14.0	14.0	14.0
50	1	7.8	9.2	11.5
50	3	9.4	11.6	14.0
50	5	11.5	14.0	14.0
50	10	14.0	14.0	14.0

Conclusion

Bates, Rayner, and Custance's conclusion that under inflation the optimal age of replacement tends to increase depends, among other things (p. 332), on the assumption that r, the relevant real discount rate, does not alter with the inflation rate. This I have shown is unlikely to hold and that under inflation the discount rate is likely to be lower thus tending to encourage earlier, not later, replacement.

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Reference

Bates, J. M., A. J. Rayner, and P. R. Custance. "Inflation and Farm Tractor Replacement in the U.S.: A Simulation Model." *Amer. J. Agr. Econ.* 61(1979):331–34.

Inflation and Farm Tractor Replacement in the U.S.: A Simulation Model: Reply

J. M. Bates and A. J. Rayner

In his comment on our recent article in this *Journal*, Bartholomew has argued that under increasing inflation, the real rate of interest tends to decline, thus encouraging earlier replacement of capital equipment than otherwise would occur. In support of this claim, evidence of interest rate movements in Australia has been presented. We shall argue that this evidence indicates that an unanticipated increase in the rate of inflation is not immediately matched by an increase in nominal interest rates, but that it says little about the effects of a sustained and constant rate of inflation. We also shall suggest small modifications to his equation (1) and to his table 1.

Inflation and Real Interest Rates

First, we must admit that an unanticipated increase in the rate of inflation almost certainly will lead to a temporary (and not necessarily short) period in which real post-tax interest rates are lowered. Similar tables can be presented for interest rates in the United Kingdom (see, for example, the article by Barr), and no doubt also for the United States and other countries. Thus, because expectations concerning the rate of inflation adjust only slowly to changes in the current rate of inflation, nominal interest rates are likely to change only slowly: this implies that real rates of interest initially will decline when inflation increases. It is, however, by no means certain that an increase in the inflation rate will, if sustained, lead to real rates of interest declining. With a given tax rate on business profits, another (possibly different) rate on unearned personal incomes, the gross return on projects, will be higher than the net return to the business, which itself is higher than the net return to the tax-paying saver. In an inflationary situation, the gap between gross business returns and net returns on savings widens, and the amount of investment/savings is reduced. The important factors here are the interaction between net returns on savings and the amount of funds made available by lenders, and the marginal efficiency of capital. Not knowing the elasticities of the two relevant functions (the savings function and the marginal efficiency of capital) we cannot say whether real post-tax returns are more likely to increase or to decrease, but we assume that, to the first degree of approximation, it will revert to an unchanged level once expectations have been fully revised to take account of the new rate of inflation. Support for our argument is given in Feldstein's article.

Relationships between Real and Nominal Interest Rates

The relationship given in Bartholomew's comment in equation (1) assumes that tax payments are made immediately after any interest is received. If, alternatively, it is assumed that tax payments and rebates occur with an average lag of one year, the relationship between real post-tax and nominal discount rates is given by the equation

$$(1) \quad 1 = \frac{(1 + R)/(1 + \Theta)}{1 + r} - \frac{TR/(1 + \Theta)^2}{(1 + r)^2},$$

where r is real after-tax discount rate, T is tax rate, Θ is inflation rate, and R is nominal discount rate. Table 1 records values for R for different values of r and Θ, given a tax rate of 25% and a one-year lag in tax payment. Nominal rates are still higher than real after-tax rates of discount, but by a slightly smaller magnitude. A mathematical expression of the difference made by having lagged tax payments and receipts is available from the authors.

Conclusion

Bartholomew quite rightly draws attention to the relationship between the rate of inflation and the

Table 1. Nominal Discount Rate, Real Discount Rate, and the Rate of Inflation, with Tax Payments Lagged One Year

Real Discount Rate (%)	Nominal Discount Rate (%) — Inflation Rate (%) 0	5	10
1	1.3	7.9	14.3
3	4.0	10.6	17.1
5	6.6	13.3	19.8
10	13.0	19.8	26.5

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real discount rate. We wish to take this opportunity to state that when the rate of inflation initially increases (assuming it does) replacement will normally be quicker while farmers take advantage of lower real post-tax rates of interest; even the modification introduced in equation (1) does not shake this conclusion, though the magnitude of the difference between real and nominal rates is lower where the settlement of taxes is lagged. But if the higher rate of inflation is sustained we would expect real post-tax interest rates to rise to their former levels, and for replacement of equipment then to be delayed.

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References

Barr, N. "Real Rates of Return to Financial Assets Since the War." *3 Banks Review* 107, pp. 23–44.

Feldstein, M. S. "Inflation, Income Taxes and the Rate of Interest: A Theoretical Analysis." *Amer. Econ. Rev.* 66(1976):809–20.

Supply Shifts and Research Benefits: Comment

Roger N. Rose

In their recent article, Lindner and Jarrett (LJ) developed a general procedure for measuring gross research benefits (*GARB*). In deriving their measure of *GARB*, LJ made a fundamental error which invalidated the bulk of their findings. The source of that error is described in the first part of this paper, and a simple alternative measure is outlined. The meaning of commodity supply curves is then discussed, and it is pointed out that the interpretation of supply price as rent-free marginal cost is incorrect. Under these circumstances, predicting whether a particular innovation will produce divergent, parallel, or convergent supply shifts is virtually impossible.

The existence of some error in the LJ procedure can be demonstrated from their comparison of parallel and pivotal supply shifts. Consider the alternative supply shifts illustrated in figure 1 below. The movement from a pre-innovation equilibrium at M_0 to a post-innovation point at M_1 is taken as being the result of either a parallel shift from supply curve A_0S_{10} to A_1S_1 or as a pivotal shift from A_1S_{20} to A_1S_1. For a parallel shift, *GARB* is given by the area $A_0M_0M_1A_1$. For a pivotal shift, *GARB* is given by the area $A_1M_0M_1$. Clearly, the value of *GARB* for a pivotal shift cannot be less than 50% of the value for a parallel shift, with an equal cost decrease at M_0. LJ presented estimates of pivotal shift values as low as 12% of equivalent parallel shift values.

The problem with LJ's analysis can be illustrated by reference to figure 2, where industry demand is given by DD_1 and pre-innovation supply is given by S_{e0}. The slopes of DD_1 and S_{e0} are based on elasticities estimated to apply at the pre-innovation equilibrium point M_0. It is assumed that the post-innovation supply curve, S_{e1}, is parallel to, and a vertical distance M_0B_1 below, S_{e0}. Following Pinstrup-Andersen, Ruiz de Londoño, Hoover, and LJ, the post-innovation equilibrium point, M_1, can be found by equations (1) and (2):

$$(1) \qquad P_1 = P_0[1 - (ke)/(e + n)],$$

$$(2) \qquad Q_1 = Q_0[1 + (ken)/(e + n)].$$

Demand and supply elasticities are n and e, respectively, (n is an absolute value) and k is the cost decrease as a proportion of P_0. Throughout this paper, k is positive for a cost decrease. LJ's analysis was made confusing by changes in signs for the parameter. In their text and in the equation defining intercept values (p. 52), k was defined as the cost decrease but in their equations (5) and (6) it was negative for a cost decrease. In the footnote to table 1 it was again positive.

The basic error in LJ's analysis arose from improperly incorporating additional information into the supply model. While the elasticities used may be valid in the region of M_0, LJ argued that the extrapolation of S_{e0} and S_{e1} to the origin could produce the incongruous result that positive quantities would be supplied at negative prices. They therefore argued that A_0 and A_1, the pre-innovation and post-innovation intercept terms, should be estimated independently of S_{e0} and S_{e1}. Their analysis then included two conflicting sets of information, one based on elasticity estimates and the other based on intercept estimates.

The end result of that conflict was a divergence between the shift which LJ intended to measure and that which they actually measured. In figure 2, for a parallel shift, the cost reduction at the origin (A_0A_1) must equal that at M_0 (M_0B_1). Having reached this point, LJ estimated *GARB* as the rectilinear area $A_0M_0M_1A_1$ for a parallel shift. But the vertical distance between M_0 and the curve A_1M_1 is equal to M_0B_2, and $M_0B_2 = M_0B_1$ only when the slopes of A_1B_1 and S_{e1} are equal. That is the trivial case where the problem which LJ set out to solve, that of elasticity estimates leading to unrealistic intercept values, does not exist. In fact, for all cases treated by LJ, M_0B_2 was substantially less than A_0A_1. Exclusion of the area $A_1M_1B_1$ from the measure of *GARB* is common to all types of supply shift estimated by LJ. For the parallel example, with M_0B_2 less than A_0A_1, LJ's estimates were for convergent, not parallel, shifts. Since the coordinates of M_1 vary with elasticity changes, the shift measured at M_0, and thus the degree of error, is different for each possible combination of e and n.

The simplest alternative measure is to use k and S_{e0} to establish the coordinates of M_1 and to estimate separately the area $M_0M_1B_1$ (X) and that between M_0B_1 and the price axis (Y), clearly specifying the value of M_0B_1. Then total benefits are given by equation (3):

$$(3) \qquad GARB = X + Y.$$

From LJ's equation (2), but substituting the coordinates of B_1 for M_1, the area $A_0M_0B_1A_1$ (Y) is given by equation (4):

$$(4) \qquad Y = \tfrac{1}{2}Q_0(kP_0 + A_0 - A_1),$$

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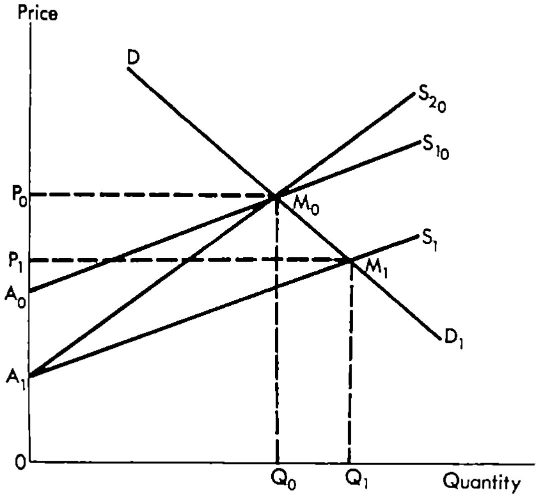

Figure 1. Parallel and pivotal supply shifts

which reduces to equation (5):

$$Y = kP_0Q_0, \tag{5}$$

for a parallel shift. Only the shift at the origin (A_0A_1) influences the area of $A_0M_0B_1A_1$, with the position of the intercept (A_0) being of no consequence except in the case of proportional shifts. In the latter case, A_0A_1 is explicitly set as a function of A_0. The relationship between values of Y for divergent, parallel, and convergent shifts is fixed by that between A_0A_1 values.

The area $M_0M_1B_1$ (X) is approximated by equation (6):

$$X = \tfrac{1}{2}kP_0(Q_1 - Q_0). \tag{6}$$

When the coordinates of M_1 are set from equations (1) and (2), that equation is strictly correct only if

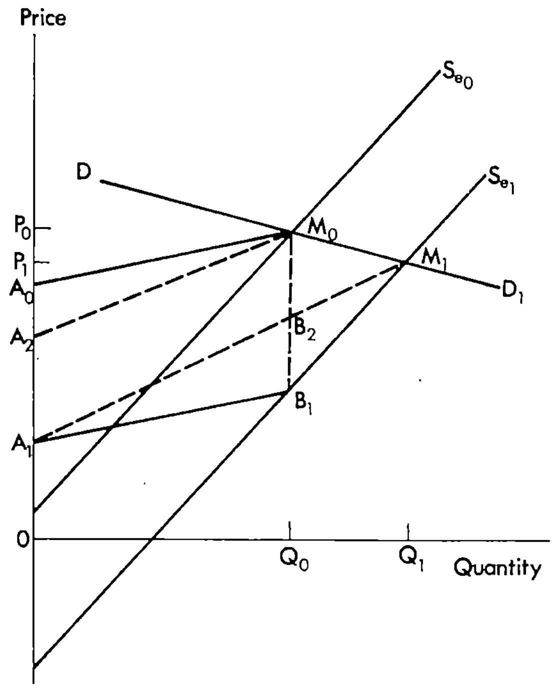

Figure 2. Intended and actual measures of benefit from a parallel shift

the shift is parallel. But X is generally small relative to Y and differences between alternative derivations are likely to be insignificant.

Given that X is relatively small and that Y is independent of n and e, changes in elasticity are of little significance for *GARB* and the relative values for different types of shifts are virtually fixed. This relative fixity of *GARB* for different elasticities can be seen to some extent in table 1. The error in

Table 1. Sensitivity of *GARB* to Assumptions About the Nature of Supply Shift: Comparison of Equation (3) Results with LJ Results (LJ Results in Parentheses)

Demand Elasticity n	Supply Elasticity e	Intercept A_1/P_1	Type of Supply Shift: Pivotal[a]	Proportional[b]	Parallel[c]	Convergent[d]
0.50	0.20	0.20	0.50 (0.29)	0.61 (0.43)	1.00 (1.00)	1.50 (2.72)
		0.80	0.50 (0.24)	0.93 (0.85)	1.00 (1.00)	1.50 (1.76)
2.00	5.00	0.20	0.53 (0.70)	0.63 (0.76)	1.00 (1.00)	1.47 (1.31)
		0.80	0.53 (0.55)	0.92 (0.91)	1.00 (1.00)	1.47 (1.45)

Note: For each elasticity and intercept combination *GARB* is expressed as a proportion of that for a parallel shift.

[a] $A_0 = A_1$
[b] $A_0 = A_1/(1 - k)$
[c] $A_0 = A_1 + kP_0$
[d] $A_0 = A_1 + 2kP_0$

measuring the variable value M_0B_2 as the supply shift, and not any actual variation in benefits, accounts for most of the sensitivity of LJ's results to elasticity changes.

Results reported in LJ's tables 1 and 2 contain a further error. Since k is defined as M_0B_1/P_0, A_0A_1 is equal to kP_0 for a parallel shift. Therefore, $A_0 = A_1 + kP_0$, not $A_0 = A_1 + kP_1$ as defined by LJ. Similarly, for a proportional shift, $A_0 = A_1/(1-k)$ not $A_0 = A_1(1+k)$. This occurred despite the fact that the relationships were properly specified in the text (p. 52). The effect of these misspecifications can be demonstrated in figure 2, where A_0 is the true estimate and A_2 is that produced from the LJ definition. Benefits equal to the area $A_0M_0A_2$ are excluded from the LJ estimate.

Using equation (3), two comparisons made by LJ were repeated. The new values, along with LJ's original estimates, are presented in tables 1 and 2. In table 1, the values of *GARB* derived from four types of supply shift are compared for various elasticities and intercept terms. P_1 and Q_1 were set at unity, and k was set at 0.1, which appears to be the value used by LJ in their table 1.

In table 2, values are given for the percentage overestimate of *GARB* produced by using Griliches' formula $GARB = kP_1Q_1(1 - \frac{1}{2}kn)$. Following Griliches and LJ, it was assumed that the supply shift was proportional and k was equal to 0.13 [since Griliches' k was defined at M_1, it is not equivalent to k in equations (1)–(6)]. Because of the assumption made in arriving at equations (1) and (2), that S_{e0} and S_{e1} are parallel, the results presented can only be approximations to a proportional shift. A parallel shift of $0.13/P_1$ was assumed to apply between M_1 and M_0, allowing equations (1) and (2) to be used to find M_0. The shift was then assumed to be proportional between M_0 and the price axis.

It is clear from tables 1 and 2 that the magnitude of error involved in using the LJ procedure is substantial. Only one of the propositions made in the first part of their paper is valid; that other writers have, at times, grossly overestimated benefits. Much of the estimated variation in *GARB* with elasticity changes was due to error. The same was true of the degree of difference found between different types of supply shift.

Table 2. Percentage Overestimate of *GARB* Produced by Applying Griliche's Formula (LJ Results in Parentheses)

Supply Elasticity[a] Intercept A_1/P_1	0.2	1.0	5.0
0.2	59	61	62
	(225)	(72)	(32)
0.5	26	29	31
	(128)	(47)	(20)
0.8	4	7	9
	(76)	(29)	(10)

[a] Demand elasticity was assumed to be 0.5 for all cases.

Although the measured difference between *GARB* for different types of supply shift is still substantial, it is doubtful if these shifts can actually be identified. The approach used explicitly by LJ and implicitly by previous authors is based on the assumption that the area above the supply curve and below the equilibrium price line (producers' surplus) is an accurate measure of surplus accruing to fixed factors of production. Only then does the change in economic surplus have any validity.

Mishan pointed out that the producers' surplus is a valid measure only when the industry supply curve is both a marginal cost curve excluding factor rents and an average cost curve including factor rents. This can be strictly true only when a single productive factor is in fixed supply and all others are in infinitely elastic supply to the industry in question. One case in which Mishan stated that these conditions would apply was the "Ricardian case of a fixed supply of land." On the "Ricardian case" rests the validity of interpreting supply curves for agricultural commodities as marginal cost curves.

That case is purely hypothetical. It is true that the aggregate supply of land is virtually fixed and therefore it would be expected that pure rents accrue to landowners in the long run. What is not true is the suggestion that this argument has a simple extension to individual commodity supply curves. Whenever there are at least two competing uses for land, the amount supplied for production of one commodity is not fixed but is a function of other commodity prices. The supply curve for an agricultural commodity therefore includes marginal rents to land (from alternative enterprises) as well as marginal nonland costs. It is not a marginal curve exclusive of rents.

Some measure of the care needed in interpreting cost and supply curves can be gained from the synthetic example presented in table 3. The hypothetical cost and returns are for two areas of land, both of which can be used to produce either wheat or barley. The first is contrived to be at the origin of the wheat supply curve, A_0, the second at the point of initial equilibrium production, Q_0. In the three cases illustrated, identical supply curves were derived from different combinations of rent and nonland costs.

Comparisons can be made from table 3 between actual cost savings, due to an innovation which reduced nonland costs of wheat production by 10%, and estimates which would be produced if supply price was assumed to exclude rent. Estimates reproduced in table 3 were made on the basis that the $6/tonne cost decrease for wheat at the origin was predicted correctly but that a 10% change was therefore assumed to apply to the initial price of $140 at Q_0, the initial market equilibrium. Such estimates could be produced, for example, if minimum average cost estimates from an economies-of-size study were taken to equal the intercept A_0. Actual benefits from such an innovation would clearly differ between the cases illustrated in table

Table 3. Points on Hypothetical Supply Curves: Rents and Other Costs Actual and Estimated Benefits from a 10% Cost Decrease for Wheat Production

Crop and Cost/Benefit Category	Costs and Benefits at the Origin		Costs and Benefits at Equilibrium Point Q_0: Case 1 Constant Rents		Case 2 Increasing Rents		Case 3 Decreasing Rents	
	A[a]	B	A	B	A	B	A	B
Barley:								
Yield (T./ha.)	1.0	1.0	1.0	1.0	1.4	1.4	0.6	0.6
Revenue ($/ha.)	100	100	100	100	140	140	60	60
Nonland cost ($/ha.)	60	60	60	60	60	60	60	60
Wheat:								
Yield (T./ha.)	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Nonland cost ($/ha.)	60	54	100	90	60	54	140	126
Barley rent ($/ha.)	40	40	40	40	80	70	0	0
Supply price ($/T.)	100	94	140	130	140	134	140	126
Cost Decrease:								
Actual ($/T.)	6		10		6		14	
Estimate ($/T.)	6		14		14		14	

[a] A is pre-innovation; B, post-innovation.

3. However, if supply price and marginal cost were considered to be equivalent, no difference would be noted between the cases. Such an approach would lead to accurate estimates only by coincidence.

When it is admitted that supply prices are inclusive of rents, the difficulty of determining the nature of a supply shift becomes apparent. Even the implication above, that low-cost (exclusive of rent) producers are likely to be close to the origin, is not necessarily true. A producer who is efficient in producing one commodity is quite likely to be efficient in producing others. In such a case, when nonland costs may be low, rents may be correspondingly high and the producer may only supply the good in question at a relatively high price.

The suggestion made by LJ, that scale-dependent innovations are likely to benefit low-cost producers close to the origin of the supply curve and therefore give rise to convergent supply shifts is unsustainable. Such producers are just as likely to have substantial potential earnings from alternative enterprises and therefore be associated with other points on the supply curve. Unless evidence exists to link particular levels of nonland cost with points on the supply curve, there is little basis on which to make assumptions about the nature of supply shifts.

One case in which the nature of the supply shift may be predictable is that of a yield-increasing innovation which does not require input changes per unit of land. For such a change, both the demand for land and the demand for other inputs would be proportionally reduced for each unit of output. Therefore, whatever the structure of rents relative to other costs, the innovation would be likely to reduce all costs proportionally. However, it is unlikely that any sensible measure of A_0, for a rent free cost curve, could be made and the critical shift A_0A_1 could therefore not be estimated.

For most innovations, the best information available may be a cost-reduction estimate for a single point on the supply curve. For the reasons outlined above, it is unlikely that any knowledge of the shape of the supply curve, or the position at which the single estimate applies, will be available. The only realistic strategy is to assume that the supply shift is parallel. This amounts simply to taking the product of the original equilibrium quantity and the estimated cost change, equation (5), and making a minor adjustment for price response as in equation (6) above.

The procedure outlined above is crude but that it also appears to be so may be useful. Previous treatments have been concentrated on increasing the geometric sophistication of explanatory models and even that has been subject to fundamental errors. What is more important is to have an understanding of supply curves and the derivation of cost changes. Geometric manipulations are of little help at that level.

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References

Lindner, R. K., and F. G. Jarrett. "Supply Shifts and the Size of Research Benefits." *Amer. J. Agr. Econ.* 60(1978):48–58.

Mishan, R. J. "What is Producer's Surplus?" *Amer. Econ. Rev.* 58(1968):1269–82.

Pinstrup-Andersen, P., N. Ruiz de Londoño, and E. Hoover. "The Impact of Increasing Food Supply on Human Nutrition: Implications for Commodity Priorities in Agricultural Research and Policy." *Amer. J. Agr. Econ.* 58(1976):131–42.

Supply Shifts and the Size of Research Benefits: Comment

William S. Wise and Elisabeth Fell

In presenting their own procedure, Lindner and Jarrett have claimed that "all previous techniques used to measure gross annual research benefits may produce biased results" (p. 48). The purpose of this comment is to draw attention to a mathematical flaw in their treatment.

As one of us (Wise) has indicated elsewhere, the shifts from one supply curve to another as technology changes are not, in general, vertical, although Lindner and Jarrett supposed that they were. However, for present purposes a vertical shift is considered. The symbols used by Lindner and Jarrett (LJ) are retained including the unitary system $P_1 = Q_1 = 1$; their numbered equations are distinguished by LJ.

The essential construction is given in figure 2 LJ (p. 50). It is convenient to label as N_1 the intersection of supply curve S_1 with the vertical through output Q_0. Also, let A_0 be expressed as $(A_1 + \alpha k)$ where for the pivotal, proportional, parallel, and convergent shifts, as defined by Lindner and Jarrett, α is, respectively, 0, A_1, 1, and 2.

The national benefit is $A_1N_1M_1M_0A_0$, and discussion centers on how this area is to be estimated. Consider first the cost curve A_1M_1. We find entirely convincing the argument of Lindner and Jarrett that an econometric supply elasticity cannot apply over the whole course of such a cost curve and, indeed, would ourselves reject the use of supply elasticities in this context altogether. However, to follow through the compromise adopted by Lindner and Jarrett, it may be supposed that A_1M_1 is constituted of two segments, viz., (*a*) from A_1 to N_1, an empirical, linear-cost curve determined by the parameters A_1 and k; and (*b*) a supply curve of elasticity ϵ having only local significance over N_1M_1. On the assumption that over the short path N_1M_1, the supply curve is approximately linear, then the national benefit can be found as the sum of the areas of trapezium $A_1N_1M_0A_0$ and triangle $N_1M_1M_0$. With $P_1 = Q_1 = 1$, with A_0 given by $(A_1 + \alpha k)$, and with M_0N_1 defined as kP_0, this reduces to

(1) $$\textit{national benefit} = \tfrac{1}{2}k(\alpha Q_0 + P_0).$$

This is not, however, the expression reached by Lindner and Jarrett. They proceeded from the assumption that N_1 lay on the straight line joining points A_1 and M_1. The assumption is only valid when the supply elasticity has the particular value which makes the slopes of A_1M_1 and N_1M_1 equal. If, as Lindner and Jarrett do, ϵ is arbitrarily varied, then the slopes of A_1M_1 and N_1M_1 generally will differ; this means that there will be a kink in the cost curve A_1M_1 at the point N_1, or, in other words, N_1 does not lie on the straight line joining A_1 and M_1.

Given the kinked cost curve which this LJ model implies, then the national benefit is as in equation (1). On the false basis that N_1 lies on the straight line joining A_1 and M_1, the national benefit would be calculated as the trapezia $A_0M_0Q_00 + M_0M_1Q_1Q_0 - A_1M_1Q_10$. The result would then be

(2) $$\textit{national benefit} = \tfrac{1}{2}(A_0 + P_0)Q_0 + \tfrac{1}{2}(P_0 + P_1)(Q_1 - Q_0) - \tfrac{1}{2}(A_1 + P_1)Q_1.$$

This reduces to equation (2) LJ. Because equation (2) incorrectly estimates the national benefit, it follows that equation (2) LJ must likewise do so.

Estimation of P_0 and Q_0

From the conditions that points M_0 and M_1 lie on the demand curve, N_1 lies on a supply curve of elasticity ϵ passing through the point M_1, and M_0N_1 is equal to kP_0, it is possible to find the values for P_0 and Q_0 as

(3) $$P_0 = (1 - k) - \epsilon/(n + \epsilon),$$

(4) $$Q_0 = (1 - k)n\epsilon/(n + \epsilon).$$

Binomial approximations can then be made, for $k << 1$, to give

(5) $$P_0 = 1 + k\epsilon/(n + \epsilon),$$

(6) $$Q_0 = 1 = kn\epsilon/(n + \epsilon).$$

Comparison of these last two equations with equations (5) LJ and (6) LJ show the latter to be in error. It is clear that they must be since $P_0 > 1$ and $Q_0 < 1$, but equations (5) LJ and (6) LJ predict the reverse. It appears that the error only lies in a misprint because we were able to reproduce the LJ tables with the correct equations (5) and (6).

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Comparison of Benefit Estimates

Various estimates of the national benefit can be made. An exact value can be found as follows. $A_0M_0N_1A_1$ is a trapezium whose area B is given by

$$B = \tfrac{1}{2}Q_0k\,(\alpha + P_0). \tag{7}$$

$N_1M_1M_0$ is a curvilinear triangle whose area can be found by integration as

$$\delta B = \frac{n}{n-1}\left(1 - Q_0^{\frac{n-1}{n}}\right) - \frac{\epsilon}{\epsilon+1}\left(1 - Q_0^{\frac{\epsilon+1}{\epsilon}}\right). \tag{8}$$

The exact national benefit is then $B + \delta B$ where δB will generally be small relative to B.

Next, a simple "trapezoidal estimate" can be made by using equation (7) but taking P_0 and Q_0 as approximately unity. This corresponds to the constructions of figures 1 LJ and the approximate national benefit is then given by

$$\textit{trapezoidal estimate} = \tfrac{1}{2}k(1 + \alpha). \tag{9}$$

A "binomial estimate" can be made by using equations (5) and (6) to find P_0 and Q_0 and then inserting these values into equation (1). Lindner and Jarrett's procedure was to insert the values of P_0 and Q_0 found from equations (5) and (6) into the incorrect equation (2) LJ.

Numerical comparisons of the various methods of estimation are given in table 1. This relates to a k of 0.13 which, we believe, was the value used by Lindner and Jarrett. For convenience, the unitary system was altered to $P_1 = Q_1 = 100$ for table 1.

Under all conditions, the binomial approximation gives an estimate close to the exact one. The even simpler trapezoidal estimate often would be acceptable given the roughness of the agricultural data which sometimes have to be used for research benefit analyses.

In contrast, the LJ procedure yields substantially different results. In particular, attention may be drawn to the sensitivity of the LJ estimate to the value of the parameter A_1. This parameter does not enter in the estimates of the pivotal. parallel, and convergent cases given by the other procedures, as can be appriciated from figures (1) LJ. All the shaded areas lie on the same base, kP_0, on the vertical line D_0Q_0; they all have the same height, Q_0. The areas of the triangle, parallelogram, and trapezium of figures 1 (*a*) LJ, 1 (*c*) LJ, and 1 (*d*) LJ, respectively, are, therefore, in the proportions 50 : 100 : 150, irrespective of the position of point A_1. The additional component of the national benefit, δB in equation (8), is independent of the parameter A_1 and is, in any case, relatively small. Hence, the national benefits in the pivotal, parallel, and convergent cases should be roughly in the proportions 50 : 100 : 150, irrespective of the position of point A_1; the results in table 1, apart from those obtained by the erroneous LJ procedures, follow this pattern.

It might be objected that the exact method still shows benefit estimates varying by a factor of 3, depending on the shift postulated. In reply to this, it

Table 1. Comparison of Estimating Procedures

			Type of Supply Shift				
				Proportional			
Procedure	n	ϵ	Pivotal	$A_1 = 0.2$	$A_1 = 0.8$	Parallel	Convergent
Exact	2	0.2	659	785	1,166	1,292	1,926
Binomial	2	0.2	658	785	1,165	1,292	1,927
Trapezoidal	2	0.2	650	780	1,170	1,300	1,950
LJ: $A_1 = 0.8$	2	0.2	83	—	590	717	1,352
$A_1 = 0.2$	2	0.2	154	281	—	788	1,423
Exact	0.5	0.2	677	804	1,186	1,314	1,951
Binomial	0.5	0.2	674	802	1,184	1,312	1,950
Trapezoidal	0.5	0.2	650	780	1,170	1,300	1,950
LJ: $A_1 = 0.8$	0.5	0.2	204	—	715	842	1,480
$A_1 = 0.2$	0.5	0.2	260	388	—	898	1,536
Exact	2	5.0	712	819	1,139	1,245	1,778
Binomial	2	5.0	710	816	1,134	1,240	1,769
Trapezoidal	2	5.0	650	780	1,170	1,300	1,950
LJ: $A_1 = 0.8$	2	5.0	650	—	1,073	1,179	1,709
$A_1 = 0.2$	2	5.0	1,207	1,313	—	1,736	2,266
Exact	0.5	5.0	736	858	1,224	1,347	1,957
Binomial	0.5	5.0	727	849	1,216	1,338	1,950
Trapezoidal	0.5	5.0	650	780	1,170	1,300	1,950
LJ: $A_1 = 0.8$	0.5	5.0	650	—	1,139	1,262	1,873
$A_1 = 0.2$	0.5	5.0	827	950	—	1,439	2,050

can first be pointed out that the convergent construction of figure 1 (*d*) LJ is an unfair comparison with the other diagrams in that the most efficient producer obtains a cost saving of $2k$, whereas in the others it is only k. Bringing the comparisons to a uniform basis reduces the factor of 3 to 2.

Second, if β is the vertical distance between curves S_0 and S_1, an approximation to the national benefit is

$$\text{(10)} \qquad \textit{national benefit} = \int_0^1 \beta. \quad dq.$$

Comparison of equations (9) and (10) shows that the assumption of a parallel shift ($\alpha = 1$) will produce the correct national benefit if

$$\text{(11)} \qquad k = \int_0^1 \beta. \quad dq.$$

Equation (11) implies that an unbiased result will be obtained if analysts assume a parallel shift but use for k a value for β averaged over all producers rather than the largest β obtainable by the most efficient producer.

Lindner and Jarrett have performed a valuable service in showing that supply curve elasticities should not be used uncritically in benefit calculations; their emphasis on the need for analysts to consider what does happen under production conditions rather than to assume that the best experimental yields will be achieved is also salutary. Nevertheless, even supposing that their model of vertical supply-curve shifts and their "kinked" cost curve were acceptable, we still must point out that their working contains a mathematical flaw, and that their numerical results are consequently invalid.

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References

Lindner, R. K., and F. G. Jarrett. "Supply Shifts and the Size of Research Benefits." *Amer. J. Agr. Econ.* 60(1978):48–58.

Wise, W. S. "The Economic Analysis of Agricultural Research." *R & D Manage.* 8(1978):185–89.

Supply Shifts and the Size of Research Benefits: Reply

R. K. Lindner and F. G. Jarrett

The central proposition in our paper on supply shifts and research benefits was that the size of *GARB* is sensitive to the nature of the shift in the supply curve induced by adoption of a process innovation. We also argued that because the available formulas for calculating *GARB* typically presumed a particular type of shift, estimation error would result from the application of such formulas if the actual shift did not correspond to that presumed. Despite the claim by Rose that "LJ made a fundamental error which invalidated the bulk of their findings," none of the arguments made in either comment have persuaded us to reject either of the above propositions. All of the comment by Wise and Fell (WF) and the first part of that by Rose relate to the calculations we carried out to numerically illustrate these propositions, and to provide some idea of their quantitative importance. The second part of the comment by Rose is a restatement of arguments contained in a paper by Mishan (1968), and in our view is a general attack on the notion of producer surplus rather than a specific criticism of our paper.

While we cannot accept all of the detailed criticisms made in the comments, we do accept the main thrust of the argument by both authors that the computational procedures underlying the results in our illustrative tables were in error; and that as a result we overstated both the sensitivity of *GARB* to the nature of the supply shift and the magnitude of the possible error which would result from using a formula based on a particular type of shift. We also have some reservations to be outlined below about the computational procedures advocated by WF and by Rose, and hence about the tables of results they derive using these procedures, but would agree that either approach is to be preferred to our earlier proposals.

Nevertheless, we note that the illustrative tables calculated by WF and by Rose still support our two main contentions, namely, that the size of *GARB* is sensitive to the type of supply shift, and that formulas which presume a particular type of shift can lead to substantial errors. According to Fell and Wise, "the exact method still shows benefit estimates varying by a factor of three, depending on the shift postulated." Similarly, it can be seen from table 1 of Rose that a formula which presumed a pivotal shift when the actual shift was convergent would underestimate *GARB* by a factor of two or more. Furthermore, there is no reason why the particular cases of a pivotal and convergent shift which we chose originally for illustrative convenience should be treated as limiting cases. It is by no means inconceivable that particular innovations might only affect marginal output, and have no effect at all on the cost of producing the bulk of intramarginal output. In such a case, the S_0 and S_1 supply curves would be coincident over much of the relevant range, so that use of a formula based on the assumption of a parallel shift would easily overestimate *GARB* by several hundred percent.

Partly because of the almost unlimited diversity in possible types of supply shift, and partly for other reasons to be discussed below, we now believe that our earlier attempt to provide a more generally applicable formula for the measurement of *GARB* also suffered from being too mechanistic. Nor do we regard the alternative formulas advanced by WF or by Rose as entirely satisfactory, since they both more or less follow the same general approach used in our original article. Accordingly, we do not propose to detail all of the ways in which we disagree with specific aspects of the above comments. Instead we prefer to take a more positive approach by discussing what we now perceive to be the state of the art.

We commence by considering the issue raised by Rose in the second part of his comment. In common with the rest of the literature on research benefits with which we are familiar, we accepted the validity of using the area below the demand curve and between the S_0 and S_1 curves as a measure of *GARB*. Rose has now challenged the underlying legitimacy of this branch of the literature, and it is with certain misgivings that we broaden the scope of our response to encompass this more fundamental issue. Rose bases his attack on an article by Mishan which was not directly concerned with the measurement of *GARB*.

If we understand Mishan correctly, he argues that producer surplus, as measured by the area above the long-run industry supply curve and below market-clearing price, does not capture all of the rent earned by the fixed factor (which we take to be land in the case of agriculture), as it has alternative productive uses in other rural industries. Thus the

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Peter Wagstaff helped clarify the authors' thoughts on a number of points, but any errors are the authors.

use of land by any particular rural industry will involve an opportunity cost which accounts for part of the area below, rather than above, the industry supply curve. We are persuaded by this argument, but do not believe that it invalidates the established procedure for measuring *GARB* which is based on the change in economic surplus, and not on its absolute value. Because that part of the rent to land which is not captured by industry-specific producer surplus is left unchanged by adoption of a process innovation, the conventionally defined area for measuring *GARB* does provide a valid measure of the change in consumer surplus plus the change in economic rent to the fixed high factor land.

Rose goes on to imply by way of the hypothetical example in table 3 that we advocated an erroneous procedure for estimating the reduction in costs consequent upon adoption of a process innovation. As described by him, the procedure would involve estimating the cost reduction at a particular point on the supply curve, and then predicting the cost reduction at some other point on the basis of an apparently arbitrarily assumed supply shift of a particular type. In the specific example presented by Rose, no explanation for choosing a proportional supply shift is provided, and the estimated reduction in cost at the supply curve intercept is used to predict that at the initial market equilibrium. This is the exact opposite of the procedure which we had in mind, but apparently we did not describe it sufficiently lucidly. In brief, our intent was that the nature of the supply shift should be determined by separate (gu)estimates of the reduction in costs at the supply curve intercept and at the market equilibrium level of output, Q_0 and not vice versa. Given our approach, as well as the ability to guess cost reductions accurately, case 2 in Rose's table 3 would have been perceived as a parallel shift, case 3 as a proportional shift, and case 1 as a divergent shift intermediate between the other two. The possibility of errors of the type which the table purports to illustrate simply would not arise because the question of how the innovation reduced costs would have been determined first.

We found the response by Rose to our challenge to debate the determinants of different types of supply shifts much more constructive. In particular, we agree with him that the rent component in supply price makes it particularly difficult to link given units of production with particular points on the supply curve. This difficulty of identifying points on the supply curve, together with the deficiencies inherent in the linearity assumption noted above, have persuaded us that we did not go far enough in our first attempt to develop a more general procedure for measuring *GARB*. Accordingly, the remainder of the discussion concerns what we now perceive to be the significant problems which should be considered in future attempts to estimate empirically *GARB*, and on the compromises involved in the feasible set of alternative procedures. In doing so, we take the view that di minishing returns have set in to *ex post* studies, and that henceforth the emphasis in the debate over the most appropriate measurement procedure should be conducted in the context of *ex ante* estimation o research benefits. In our opinion, this necessarily restricts the feasible set of techniques to those which are computationally simple and relatively undemanding in terms of required data.

The problem of measuring *GARB* can be decom posed into the following three principal subcompo nents: (*a*) estimating the size of the shift, which ha usually been measured by the size of the vertica downward shift of the supply curve at the 'without innovation' equilibrium level of output, Q_0; (*b*) es timating the type of shift, which necessarily implie estimating the reduction in costs at one or mor additional points on the supply curve (e.g., $A_0 - A$ in our previous article); (*c*) estimating the expan sion in output induced by adoption of the innova tion, (i.e., $Q_1 - Q_0$).

Empirical studies typically have made th simplifying assumption that supply curves can b satisfactorily represented by a relatively simpl mathematical function, and most of the early stud ies avoided (2) by using a formula which presume a particular type of supply shift (typically eithe parallel or proportional, but sometimes pivotal). B estimating the size of the shift at Q_0, problems o the type raised by the second part of Rose's com ment were avoided, so the essence of the problem was reduced to determination of the parameters o the "with innovation" market equilibrium, and es pecially Q_1. This was a familiar problem to econo mists, and only required estimates of local suppl and demand elasticities, plus an estimate of the siz of the shift at Q_0. Part of the motivation for writin our original paper was the belief that the use of suc formulas for calculating *GARB* was too mechanisti and, in particular, diverted attention towards th relatively unimportant question of supply and/o demand elasticities, and away from the more impor tant issue of the effect of adoption of the innovatio on production costs.

In an attempt to develop a more generally appli cable formula that allowed for different types c shift, we explicitly introduced a consideration c how the innovation affected production costs at th intercept of the supply curve with the vertical axi as well as at Q_0. Notwithstanding the contrary clai by Wise and Fell, we still maintain that given th coordinates of the four corner points A_0, A_1, M_0, an M_1, our equation (2) does compute *GARB* correctl provided that supply and demand curves are linea However, in our illustrative calculations, we faile to recognize that this simplifying assumption c linearity was violated by the procedure of estima ing P_1 and Q_1 from P_0 and Q_0 using a value of th local elasticity of supply which was not necessaril consistent with the arc elasticity of supply implie by the chosen values of A_1 relative to P_1, Q_1. As

result, the computed values of *GARB* on which our tables were based did not measure the benefits of the types of shifts which we intended.

To get around this problem, both WF and Rose partially abandon the linearity assumption by introducing a kink in the S_1 curve at the "without innovation" equilibrium level of output Q_0. As a result, *GARB* is represented by a pentagonal area which can be measured quite easily by partitioning into a trapezium and a triangle. While this device satisfactorily overcomes the principal cause of the errors in our illustrative examples, it leaves untouched three problems which are likely to cause serious difficulties in empirical studies.

The first of these relates to the use of an estimate of local elasticity of supply derived from an econometric study to calculate Q_1 from Q_0, as this implicitly assumes that adoption of the innovation does not alter the local elasticity of supply. We know of no evidence to support such an assumption, nor can we think of reasons why this should generally be the case. Indeed, innovations specific to marginal locations are likely to alter the local elasticity of supply, as are more widely applicable innovations such as the development of plant varieties which are more responsive to fertilizer and other purchased inputs. Hence we believe that considerable caution should be exercised in using local elasticity of supply estimates to calculate Q_1 from Q_0 (or vice versa).

One alternative approach which does not utilize such econometric estimates of local elasticity of supply, but retains linear supply curves as well as the same procedure for estimating the nature of the supply shift from cost reductions at zero output and Q_0, would be to determine Q_1 by linear extrapolation of the S_1 curve to its point of intersection with the demand curve.[1] Once the four corner points of the tetrahedra have been located in this manner, equation (2) from our previous paper could then be used to calculate its area. It could be argued that this procedure has a slight advantage over those discussed above in terms of computational simplicity, but this is achieved only by making a possibly even more unrealistic assumption about the local elasticity of the S_1 supply curve, and hence incorrectly estimating Q_1.

The only other alternative we can think of is to rely on expert opinion to estimate $(Q_1 - Q_0)$. One suspects that those sufficiently expert on both industry production conditions and the characteristics of the innovation in question, and especially its location specificity, are unlikely to fully comprehend the significance of an inelastic demand curve. However, errors in estimating $(Q_1 - Q_0)$ normally will be relatively unimportant since they only affect the area of the triangle, which is typically small in relation to the area of the trapezium. In those less common cases where the output-inducing effect of the innovation is large in relation to inframarginal output, we think that this rather subjective approach will almost always provide superior predictions to those based on a more mechanistic procedure.

The second problem is really a set of problems that relates to determination of the size and type of the supply shift. It is further complicated by the fact that its nature differs somewhat depending on whether the process innovation increases yield per unit of land, reduces "nonland" costs per unit area, or is some combination of the two. For the sake of expositional simplicity, only the two pure types of strictly yield-increasing, and strictly cost-reducing innovations are considered below. For an innovation which reduces only the "nonland" costs of production, but by varying degrees for different sets of output (e.g., from different parcels of land), it is necessary to identify the particular units of output corresponding to the points A_0 and M_0 on the S_0 supply curve to correctly determine the size and nature of the supply shift. Marginal output probably can be readily identified either from recent experience, or by expert opinion, but the former will be of no assistance in identifying the unit of output at A_0, and the latter most likely would need to understand the principle of comparative advantage to do so with tolerable accuracy.

For strictly yield-increasing innovations, it is supply price (i.e., marginal cost) rather than just the "nonland" cost component which is of concern. As this equals market-clearing price at the margin, estimation of the size of the shift at Q_0 should not be unduly difficult. However, estimation of $(A_0 - A_1)$ is doubly difficult for this type of innovation, since not only does the ultimate intramarginal unit of output need to be identified, but the opportunity cost component of the land rent for this unit of production needs to be measured. This component of rent cannot be observed directly since land prices reflect both the industry specific and opportunity cost components of rent. Nor does imputation of this component by calculating the rent to land in the next best use represent a practicable alternative for *ex ante* studies. Possibly the best that can be done is to establish upper and lower bounds (using market clearing product prices and solely nonland costs, respectively), and maybe undertake limited sensitivity analysis.

The third problem concerns the inflexibility, in terms of ability to accommodate different types of supply shift, inherent in the linearity assumption, or for that matter any other mathematically tractable function used to represent the supply curve. The idea of WF and of Rose of introducing a kink into the S_1 curve offers the potential of some gain in flexibility without unduly sacrificing computational

[1] Estimates of *GARB* derived from this procedure would be slightly larger than those calculated using the WF or Rose procedures and the same values for cost reduction, etc. Note also that in contrast to the Rose procedure, both *GARB* itself as well as its sensitivity to the type of supply shift will be influenced by the chosen value of A_0.

simplicity. Such an approach is implicit in the discussion above where the problem of estimating induced output ($Q_1 - Q_0$) was divorced from determination of the type of supply shift for inframarginal output (i.e., up to Q_0). The alternative is to approximate the use of integral calculus to measure the area representing *GARB*. Specifically, this would involve subdividing the production area into homogenous regions in terms of the impact of the innovation in question on yield and production costs. Within each region, a parallel shift could be presumed without risk of serious error. For innovations which only reduce costs without affecting yield per unit area, the sum of all the cost savings on intramarginal land would be approximately equal to the area of the trapezium, and the principal problem would be to identify the additional areas of land which would be induced to enter the industry as a result of the reduction in costs from adopting the innovation. The cost savings from this additional land would need to be (approximately) halved before adding to the inframarginal cost savings, since its net contribution to *GARB* is the triangle $M_0M_1B_1$ in Rose's figure 2. Yield increasing innovations pose additional problems, since output from intramarginal land (in terms of S_0) will produce output greater than Q_0 once the innovation is adopted. In fact, if demand is sufficiently inelastic, the rent which some previously intramarginal land could earn in the industry will fall below its opportunity cost, and consequently will be switched into production of other commodities. Apart from estimating the extent of this switch, there is the additional problem discussed above of estimating the opportunity cost component of land rent to include in supply price for the purpose of calculating the change in social surplus.

To sum up, there are a number of possible procedures which could be used to measure *GARB*, but no one procedure is clearly superior to the others under all possible circumstances. All of the alternatives involve compromises of one form or another and all are deficient in one or more respects. Purely cost-saving innovations present fewer problems but many innovations also alter yield per area, so that in general the extremely difficult problems arising from the fact that land has alternative uses in different industries cannot be avoided.

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References

Currie, J. M., J. A. Murphy, and A. Schmitz. "The Concept of Economic Surplus and Its Use in Economic Analysis." *Econ. J.* 81(1971):741–99.

Lindner, R. K., and F. G. Jarrett. "Supply Shifts and the Size of Research Benefits." *Amer. J. Agr. Econ* 60(1978):48–58.

Mishan, R. J. "What is Producer's Surplus?" *Amer Econ. Rev.* 58(1968):1269–82.

mpact of Farm Size on the Bidding Potential for gricultural Land: Comment

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'he theoretical model of farm size and farmland rice bidding potential developed by Harris and Iehring (HN) and published in the May 1976 *Jour-al* has been referred to as significant in explaining ıctors affecting farmland price competition (Lee nd Rask, Stanton, Carter and Johnston). As de-ate will likely continue over family farm problems nd future farm policies (Bergland), further re-earch using the HN model is to be expected. esearchers already have extended the HN model. ıdams regarded the HN model as providing a roader framework than previous models for in-estment decisions. He considered the bid prices onceptually more general and complete than deci-ion rules based solely on present value. Harris and Iehring (1977) extended the model to include a andom element.

he Bid-Price Model

IN states the maximum bid price of an acre of armland as

$$B = E(z) - \frac{1}{r(x)} \pm \left\{\frac{1}{[r(x)]^2} - \sigma_z^2\right\}^{\frac{1}{2}},$$

or $r(x) \neq 0$, and $B = E(z)$ for $r(x) = 0$, where B is he maximum price for an acre of land; z, the dis-counted value of future income; E, expectation perator; x, net worth of the decision maker; $r(x)$, Pratt's measure of local risk aversion; and σ_z^2, the variance of z.

The discounted value of future income from an ıcre of land, z, is derived from a standard per-etuity model incorporating a constant rate of growth: $z = y \dfrac{(1-t)}{(i-g)}$, where y represents a ran-lom before-tax income stream, t is the marginal ncome tax rate of the decision maker, i is the lecision maker's pure time preference, and g is the expected rate of growth of after-tax income. Thus, $E(z)$ and σ_z^2, respectively, become

$$(1) \qquad E(z) = \frac{(1-t)}{(i-g)} E(y), \text{ and}$$

$$(2) \qquad \sigma_z^2 = \left[\frac{(1-t)}{(i-g)}\right]^2 \sigma_y^2.$$

A real solution for maximum bid price B is feasi-ble if and only if $\dfrac{1}{[r(x)]^2} - \sigma_z^2 \geq 0$, or

$$(3) \qquad r(x) \leq \frac{1}{\sigma_z}.$$

That is, the rate of risk aversion has to be less than or equal to the inverse of the standard deviation of the value of an acre of land.

HN, in discussing the effects on the bid price of the marginal tax rate of the decision maker's time preference, and expected growth rate of after-tax income (p. 163), evaluate the signs of the effects with a rather ambiguous qualification: "under rea-sonable assumptions about the sizes of the param-eters in the model." The ambiguity is a result of the uncertainty regarding the sign of

$$(4) \qquad \left[\frac{E(y)}{(i-g)} - \frac{(1-t)\sigma_y^2}{D(i-g)^2}\right] \gtrless 0,$$

which affects the signs of

$$(5) \qquad \frac{\partial B}{\partial t} = -\left[\frac{E(y)}{(i-g)} - \frac{(1-t)\sigma_y^2}{D(i-g)^2}\right] \gtrless 0,$$

$$(6) \qquad \frac{\partial B}{\partial i} = -\frac{(1-t)}{(i-g)}\left[\frac{E(y)}{(i-g)} - \frac{(1-t)\sigma_y^2}{D(i-g)^2}\right] \gtrless 0, \text{ and}$$

$$(7) \qquad \frac{\partial B}{\partial g} = \frac{(1-t)}{(i-g)}\left[\frac{E(y)}{(i-g)} - \frac{(1-t)\sigma_y^2}{D(i-g)^2}\right] \gtrless 0,$$

where

$$(8) \qquad D = \left\{\frac{1}{[r(x)]^2} - \sigma_z^2\right\}^{\frac{1}{2}}.$$

Further consideration of equation (4) will clarify the ambiguity. From equations (1), (2), and (8), (4) becomes

$$(4') \qquad \frac{E(z)\left\{\dfrac{1}{[r(x)]^2} - \sigma_z^2\right\}^{\frac{1}{2}} - \sigma_z^2}{(1-t)\left\{\dfrac{1}{[r(x)]^2} - \sigma_z^2\right\}^{\frac{1}{2}}} \gtrless 0,$$

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Table 1. The Properties of the Rate of Risk Aversion Based on the 1969 Iowa Cash-Grain Farn and Farmers

Farm Class	Rate of Risk Aversion or Measure of Concavity	$R = \frac{E(z)}{\sigma_z\sqrt{[E(z)]^2 + \sigma_z^2}}$	Concavity Constraint $1/\sigma_z$	Margin Incom Tax Ra
0	0.00000298	0.01190	0.01211	.43
I	0.00000594	0.00922	0.00938	.32
II	0.00000699	0.00967	0.00985	.28
III	0.00000709	0.01218	0.01240	.25
IV	0.00001467	0.00926	0.00976	.24

the sign of which is determined by

$$(4'') \qquad E(z)\left\{\frac{1}{[r(x)]^2} - \sigma_z^2\right\}^{\frac{1}{2}} - \sigma_z^2 \gtreqless 0.$$

Solving (4″) for $r(x)$ and letting

$$R = \frac{E(z)}{\sigma_z} \cdot \frac{1}{\sqrt{[E(z)]^2 + \sigma_z^2}},$$

then, when $r(x) < R$, (4) is greater than zero, and it follows that equations (5) and (6) are less than zero and equation (7) is greater than zero. When $r(x) > R$, (4) is less than zero, and it follows that equations (5) and (6) are greater than zero and equation (7) is less than zero. Finally, when $r(x) = R$, equations (4), (5), (6), and (7) all equal zero.

The R-value is quantified in table 1 using the HN data for the 1969 Iowa cash-grain farms and farmers. Assuming normal distribution for the value of an acre of land, R is the standard normal mean value of an acre of land deflated by a term in the square-root of the sum of the mean square and the variance. The correct interpretation of equations (5), (6), and (7) is contingent upon the inequality relationships between R and $r(x)$.

Policy Implications

Implications considerably modifying the interpretation of the HN model, e.g., "Harris and Nehring note that their present value formula implies that individual valuations decrease as the marginal income tax rate rises and high income persons *ceteris paribus* bid less for farmland than do persons in lower tax brackets" (Adams, p. 540), can be drawn from these results. Given the bid price formula B and relation (3), a necessary and sufficient condition for a decision maker to have a maximum bid price to compete in the land market is that the concavity of his utility function (which is synonymous with his rate of risk aversion according to Pratt) measured at his net worth has to be less than or equal to $1/\sigma_z$. Therefore, $1/\sigma_z$ will be called th concavity constraint.

Table 1 shows that all five classes of Iowa cash grain farmers of the HN example satisfy the cor cavity constraint and have their respective biddin price. However, the utility function used by HI has little concavity. Without knowing every farm er's utility function and his rate of risk aversion, th net result of marginal income tax rate manipulatio in the context of the HN model is uncertain. De termining the effects of a change in the marginal ta rate on farmland bid prices is far more complicate than Adams has asserted.

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References

Adams, Roy D. "The Effect of Income Tax Progressivity on Valuations of Income Streams by Individuals." *Amer. J. Agr. Econ.* 59(1977):538–42.

Bergland, Bob, Secretary of Agriculture. Remarks prepared for delivery before the National Farmers Union Convention, Kansas City, Mo., 12 Mar. 1979.

Carter, Harold O., and Warren E. Jonnston. "Some Forces Affecting the Changing Structure, Organization, and Control of American Agriculture." *Amer. J. Agr. Econ.* 60(1978):738–48.

Harris, Duane G., and Richard F. Nehring. "Impact of Farm Size on the Bidding Potential for Agricultural Land." *Amer. J. Agr. Econ.* 58(1976):161–69.

———. "Impact of Farm Size on the Bidding Potential for Agricultural Land: Reply." *Amer. J. Agr. Econ.* 59(1977):388–90.

Lee, Warren F., and Norman Rask. "Inflation and Crop Profitability: How Much Can Farmers Pay for Land?" *Amer. J. Agr. Econ.* 58(1976):984–90.

Pratt, John W. "Risk Aversion in the Small and in the Large." *Econometrica* 32(1964):122–36.

Stanton, Bernard F. "Perspective on Farm Size." *Amer. J. Agr. Econ.* 60(1978):727–37.

Publications

Books Reviewed

Cochrane, Willard W. ***The Development of American Agriculture: A Historical Analysis.*** **Minneapolis: University of Minnesota Press, 1979, vii + 464 pp., $25.00, $10.95 paper.**

Harry Truman had a favorite phrase: "The only thing new in the world is the history you do not know." Some of us who thought we knew just about every facet of Willard Cochrane's professional personality—by having read his books and articles, and by having labored, disputed, and progressed with him through more than four decades—find something "new" in this book, given to us by Cochrane the historian. Historical content sets this work apart; the balance is vintage stuff, resting on such books as *Farm Prices—Myth and Reality*, and the author's other works. And the "newness," exposited as historical analysis, has given us one of the most useful books in a decade on policy issues of the United States agricultural sector. The economic analysis is so well-integrated with intertemporal political and social realities that some might conclude Cochrane missed his calling and should have written history instead of economics as a career!

After a brief introduction the subject matter model—historical analysis—is divided into three parts: a straightforward description of the historical development of American agriculture 1607–1978, an identification of key forces during that development, and a politicoeconomic model explaining the development from 1950 forward. Some concluding remarks follow in a brief chapter.

Cochrane, the historian, covers the waterfront for 156 pages (pp. 13–169) and the 371-year period 1607–1978. Professional historians, especially process historians, might quibble with method, but Cochrane's coverage is quite adequate for policy background purposes, and he gives generous references. Benedict, in his book *Farm Policies of the United States, 1790–1950* approached early policy matters from a topical-functional standpoint. The two approaches are complementary and give excellent source material.

Cochrane, the economist, restricts himself to the last three decades (pp. 355–425). It is difficult to identify his role in that large part of the book between history and economics (pp. 173–352) in which he states that he is not specifying a model of economic development but is unraveling the historical scenario by identifying the key forces during its development. This modest restriction does not jibe with the historical specification outlined for the period 1607–1950. And a major problem arises in that the casual reader may not take seriously the author's statement about his overall approach, and may wonder how everything ties together when reaching the end of the book.

Be that as it may, Cochrane, the diagnostician of history, tempered by (a new?) Cochrane, the politicoeconomist, has written his material so well and has so skillfully discriminated his market—that there is something here for many readers—for farm leaders, politicians, students, professional economists and consumers. It is only on occasion that the author lapses into seemingly rigid positions with which so many of his past critics have taken issue. This reviewer dubs one such position as Cochrane, the mercantilist. For example, he advocates that the United States abandon policies for trade liberalization in exchange for international bilateralism and other price and some trade stabilizing schemes (pp. 423 ff.) This "old" Cochrane, if he had retreated further and had included in his history a bit of sixteenth and seventeenth century England, might have learned the bitter results for much of the world of such trade policies.

In summary, the principal thesis of this book is that United States agricultural development proceeded from voluntary coordination during the period 1607 to the Great Depression, when "uncoordinated government" intervention (i.e., between Congress and the executive branch) took over for a period of about four decades. Two new phenomena emerged after 1970: more coordination between Congress and the executive, which meant an era of managed government intervention; and, second, a significant integration of the United States agriculture into the world economy via massive agricultural exports. The reviewer adds: all the while, the role of farm leaders and farm organizations in the origin and promulgation of agricultural policy was giving way to an analytical elite at various levels. In this post-1970 situation, federal as well as other policy "experts" have been constantly fine-tuning agricultural demand and supply models while hovering over computer terminals to get the latest answers for urgent political decisions.

Paul Kelly spent the spring of 1980 with me analyzing and diagnosing farm policy, arguing and disputing Cochrane's theses all the way. I conclude with several questions we raised during that time which might be of interest to Cochrane if ever he revises the book. What can we anticipate for the future role of the democratic ideal of Jeffersonian "farm policy"? Have we moved irreversibly to an era where highly concentrated farm policy planning and development will overshadow the noncentralized planning and development of policy? Will the agricultural sector, as Don Paarlberg implies, continue to lose the freedom to choose its future course, i.e., freedom to follow a path of uncoordinated intervention as it has in the past?

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Dent, J. B., and M. J. Blackie. ***Systems Simulation in Agriculture.*** **London: Applied Science Publishers, 1979, x + 180 pp., $28.75.**

A major obstacle to teaching the use of systems analysis in the agricultural sciences has been the lack of an introductory textbook. Published materials on systems analysis have dealt mostly with advanced topics. Undergraduate students and trained disciplinary researchers in agriculture have not had available a source that was at once introductory and comprehensive. Dent and Blackie have managed to fill that void.

The authors believe that a computer-based simulation model is an integral part of systems research. It can provide the framework for guiding agricultural experiments, accumulating and assessing results of these experiments, and assisting decision makers in controlling the system being modelled.

The bulk of the text is concerned with construction and operation of computer-based simulation models. Throughout, the authors intertwine examples from two simulation models with which they have had earlier association. One is a barley-leaf-rust model; the other is a pig-herd management model. A chapter devoted to model construction includes a discussion of a difficult problem in any area of scientific endeavor—where to begin. Their example models are used to good advantage in discussing the process of model construction.

Chapters are included on computer considerations in modelling (choice of language and design criteria), stochastic versus deterministic considerations in modelling, and validation of simulation models. The generous use of examples makes the presentation clear and the concepts easy to comprehend. A chapter on design of simulation experiments, though far from complete, explores the differences between these and real-world experiments: the total control over the experimental environment, time compression, and sequential rather than simultaneous nature of experimental events. For each chapter, a carefully selected bibliography has been prepared for the more serious reader.

The final chapter discusses applications of computer-based simulation models. The authors present several flowcharts that demonstrate the important role of simulation models in the orientation of agricultural research programs as well as in the development of recommendations for farmers.

Although the book is somewhat longer on the "how to" than on the "why," it successfully steers away from a simple cookbook approach to modelling. The authors recognize that many options are available during the various stages of model development and use; they present cases for and against each of the major approaches. Their overriding concern is that the model must fit the problem under consideration—not the reverse. Their tips on flowcharting, design, programming, and validation of simulation models demonstrates the breadth of their experience. Even experienced modellers can learn much from reading this text, and many modelling resources could be saved by considering the advice.

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Gardner, Bruce L. ***Optimal Stockpiling of Grain.*** **Lexington, Mass.: D.C. Heath & Co., 1979, xii + 175 pp., $19.95.**

The eight chapters of this book focus essentially on two interrelated issues: (*a*) the logical development of generalized stockpiling principles and (*b*) the application of those principles to the U.S. and world wheat situations. This combined focus, possibly as a result of Gardner's experience as a senior staff economist with the Council of Economic Advisers, provides the reader with valuable insights into the theoretical and strategical complexities of grain storage.

The first five chapters use hypothetical quantitative examples to develop storage rules for determining the optimum level of carryover stocks. Optimum is defined as that level which maximizes the present value of grain held over an indefinite time period minus the costs of production and storage and adjusted for external benefits and costs incurred. Beginning with a relatively simple two-period welfare function, the author uses stochastic dynamic programming techniques to build increasingly complex storage rules. Gardner proceeds to analyze the effect on optimum stockpile size of variations in planning horizon, elasticities of supply and demand, storage costs, random components in the production and demand of the stockpiled commodity, and the supply of close substitutes. Having set forth the economic rationale for stockpiling grain from both social welfare and private speculative viewpoints, the later chapters apply and adapt that rationale to the world wheat market and, finally, to the U.S. wheat market.

As a result of the analysis, Gardner concludes that appropriate grain-stockpiling strategies can be formulated based on principles and procedures employed in analysis of other types of economic activities, viz., maximization of a specified objective function by means of an appropriate technique subject to detailed constraints. Optimum stock levels therefore are unique to specific supply and demand conditions and must be recalculated over time. Although either price or quantity indicators may signify the need to adjust optimum stock levels, the reader becomes acutely aware of the risk of misspecified price bands and the need for absolute quantitative limits on stocks.

Gardner's analysis indicated the need for an average international wheat reserve of about 40 million metric tons with considerable annual variation. This average optimum was reduced to 10 million metric tons when price expectations were not al-

owed to impact intended production and when external costs due to shortfalls were not considered in he model. No attempt was made by Gardner to leal with the independent and often conflicting polcies of individual wheat-importing and -exporting nations. Instead, he assumes a single worldwide lecision rule commonly adhered to by all nations in estimating optimal reserve levels.

The impact of related commodities on optimum stockpiles, a factor appearing in the author's discussion of storage principles, is not included in either of his applied studies of wheat. An accounting for the impact of supply and demand of substitute grains would greatly enhance the usefulness of the applied analysis for policy makers.

In spite of these shortcomings, all of which the author is fully aware, the book makes a valuable contribution to the understanding of grain-stockpiling strategy. Gardner displays a thorough knowledge of storage literature and a keen insight into the relative value and weakness of previous studies. His own study represents a major positive addition to the literature.

The step-by-step development of optimum storage rules and their application makes this book an excellent text for graduate courses in the economics of grain storage. In total, Gardner has done an admirable job of addressing the "need to put the relevant theoretical work of economists in a form more directly usable by policy makers" (preface) and more easily understood by students.

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Gold, Steven David. *Property Tax Relief*. Lexington, Mass.: Lexington Books, 1979, xi + 331 pp., $29.95.

One of the significant events in local finance over the last ten to twenty years has been the decline of the local property tax from its premier status as the source of local revenue. Gold sets out to analyze the various property tax relief measures, in order to overcome three drawbacks that he finds in the current literature: a "paucity of timely material, . . . huge gaps concerning analysis of specific relief alternatives, . . . [and] that many writers were politically naive" (p. xv). Perhaps his most important contribution is to provide "one-stop shopping" for those interested in knowing more about this subject. As at many one-stop shopping centers, convenience comes at the cost of some sacrifices in both selection and quality.

A writer of a book like this one has to make fundamental judgments when he starts. Should the book include only the programs of which people normally think when they begin to talk about property tax relief programs, such as differential assessment of farmland? Or should it also include the wide variety of programs, such as the grant programs of the Law Enforcement Assistance Administration, that may effectively be property tax relief programs but are not commonly thought of in that context? Gold takes the latter course. Along with the narrowly defined relief programs, such as residential circuit breakers, differential assessment of farmland, classification, and property tax limits, he also includes chapters on local sales and income taxes, user charges, and miscellaneous forms of relief. The book closes with a chapter on "Rural-Urban Conflict," case studies of three states and capsule summaries of the property tax situation in each state.

In opting for the broader category, Gold, to his credit, avoids leading unwary readers to consider only part of the problem. Too many erstwhile property tax relief discussions have failed to recognize the need to find other ways of raising the funds lost from tax relief or else to cut government spending. As a result of Gold's decision, however, the sheer scope of his subject matter becomes a problem. Discussions of particular programs often must be so brief they barely scratch the surface. In many ways the book becomes a text on local revenues, though it would need heavy supplementing to be used for that purpose.

Specialists will be bothered by some instances of mistaken facts or failure to specify exactly what is meant. For example, Gold talks of property taxes rising from 1945 to 1971 "from 2.5 to 6.9 percent of farm income" (p. 118). The comparisons cited are actually to the total personal income of the farm population, a related but considerably different measure. Again, Gold suggests that no states apply roll-back penalties when land changes ownership without changing use (p. 115). He appears to have overlooked Minnesota (Waldo and Yoho, p. 4).

In a somewhat different vein, this reviewer would not necessarily agree with all of Gold's conclusions. For example (p. 120), studies of differential farmland assessment "are somewhat out of touch with the reality of farm property tax relief programs in that they tend to overemphasize the goal of preserving farmland relative to the goal of enhancing the income of farmers." I would certainly agree that these programs have had more impact on farm income than on farmland preservation. However, my observation has been that they are more often sold to the public and the legislatures as farmland preservation programs. Hence, it makes sense for those who are interested in providing information for policy determination to analyze them in that vein.

Despite these fairly minor shortcomings, the book is likely to be useful for some members of our profession. In particular, it is a good place for an extension public policy analyst to get "a quick study" of the wide variety of property tax relief measures available. Others who need a broad overview will find it here. Lexington Books would do

these readers a real service if they found ways to publish at more reasonable prices.

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Reference

Waldo, Arley D., And Carole B. Yoho. *Provisions for Use-Value Assessment of Agricultural and Open Space Land in Minnesota*, pp. 17–21. Dep. Agr. and Applied Econ. Staff Pap., University of Minnesota, 1977.

Roumasset, James A., Jean-Marc Boussard, and Inderjit Singh, eds. *Risk, Uncertainty and Agricultural Development*. College Laguna, Philippines: Southeast Asian Regional Center for Graduate Study and Research in Agriculture; New York: Agricultural Development Council, 1979, 437 pp., $40.00.

A number of pioneering economists working on technological, institutional, economic, and social issues of agricultural production in lesser income countries have long been concerned with the role of risk and uncertainty relative to technology adoption, distribution, and policy issues. With financial and logistic support from the Agricultural Development Council (ADC) and the International Center for Improvement of Wheat and Corn (CIMMYT), a conference was held near Mexico City in March 1976, which brought together more than two dozen economists. A synopsis of the seminar papers was published in 1977 by ADC, followed in 1979 by publication of this book.

The book contains twenty-one chapters which represent, for the most part, revised and synthesized versions of the seminar papers by topic categories assigned in the seminar. The first five sections focus upon alternative quantitative methods for modeling decision making under risk, measuring risk and risk attitudes, and the effect of risk on resource allocation. The last two sections focus upon risk and agricultural policy.

The title of the book suggests that it deals with concepts which link risk and agricultural development. Yet, one of its editors states in the very first paragraph of chapter one, "The book provides a survey of alternative methods in . . . agricultural decision analysis," an apparent inconsistency with the book title. Consequently, this review will concentrate upon the usefulness of the book both in covering risk methods and in covering issues of risk and agricultural development.

The topic of risk cannot be divorced from the realities of risk, even for economists, as evidenced by a vast growth in literature on this topic in the last decade. An unfortunate, yet predictable, event was the approximate four-year lag from the 1976 conference until publication of this book. Many of the chapters have been published elsewhere, supplemented by a vast quantity of work, extended and published elsewhere, or dominated by more recent publications on the same topic. The reviewers feel that, at the time of the conference, the material provided an excellent assessment of the art to the participants and those outsiders receiving working drafts. Alas, the participating economists were equally as vulnerable as everyone else in *ex ante* prediction, including that for growth in the supply of risk research literature.

Several points are troublesome within the context of the book as a text in risk methods. First, there is the issue of duplication. Chapters 2, 3, and 4 involved considerable overlap, for example. Second, it is a herculean editorial task to integrate a book containing a collection of papers, a task rarely accomplished. The result is a number of contradictory statements. Consider, for example, the statement on page 95, "expected utility applied to static decision problems . . . does not rest on reasonable behavioral postulates," versus the statement on page 46, "expected utility . . . is controversial only to the extent that some critics do not believe in subjective probabilities and others (behavioralists) challenge the . . . foundations." Obviously, a critic and a defender were participants. It is unfortunate that a resolution, or at least a consistent evaluation was not provided. On a positive note, it is refreshing that a sensible discussion of strengths and weaknesses of several quantitative techniques, especially on Bernoullian decision theory and other models of uncertain decisions, were provided. In general however, as stated in chapter 1, only a very limited attempt was made at resolution of technique choice selection. That issue is still largely unresolved today.

The third difficulty with the book, as a text in risk methods, relates to the empirical side. Because emphasis was on risk techniques, little focus was upon the equally important topic of the role of risk in an agricultural development environment. Such questions as: (*a*) are risk considerations important? (*b*) do risk attitudes differ within and among farmer groups? and (*c*) how might risk considerations improve the ability of economic models to function in analysis of positive and normative settings? were hardly addressed at all. To the extent that they were, two points are noted. First, Binswanger provides guidelines for addressing those substantive questions, but unfortunately, not until chapter 20. He further states, and correctly so, why it is important to address such issues, and why the authors of the book did not do so. The reader, because of this, may wish to read chapter one first, followed by chapter 20, before advancing further. Second, some empirical evidence was provided to suggest that, in lesser income countries, considerable diversity of farmer attitudes to uncertainty may prevail, ranging from risk averse to risk preferred. Further, this may be influenced by the economic environment (degree

subsistence living, tenure status, etc.) within hich the farmer operates. Also suggested by hnson and Lipton were nonmonetary values and havioral issues. More rigorous investigation of ch factors will most certainly be necessary before uch confidence can be placed in using arbitrary havioral decision rules for modeling uncertainty agriculture.

Considering whether the book is an integration of sk and development leads these reviewers to ach a negative conclusion. Of the twenty-one apters, only nine deal with lesser income counies, and three of those use such countries only in example mode rather than address development sues per se. The focus was largely upon farmer sk attitudes and their effect upon technology loption. This is not surprising, given that most sk methods to date are individual decision maker iented. Group decision making by credit institutons, research organizations, governments, and licy makers received scant attention because lit formal analysis has yet been done on this topic. hus, the practitioner of development will not find is book to be of great current significance in relatg risk to development problems. Binswanger's nclusion in appraising the literature's inadequacy worth repeating, as it represents major issues for solution: (*a*) scarcity of empirical evidence on obability distributions of decisions which focus on particular development problems, (*b*) scarcity empirical evidence on attitudes toward risk by velopment actors, and (*c*) limited knowledge out risk-specific policy alternatives and their efct upon development actors.

Major opportunities remain in assessing the role risk and uncertainty as it pertains to agricultural velopment problems. This book provides a useful int of departure, circa 1976, for further inquiry.

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regon State University
ruce McCarl
urdue University

rong, Ann L. *Land Banking*. Baltimore, Md.: Johns Hopkins University Press, 1979, xii + 312 pp., $22.50.

ased on original research conducted in Sweden, e Netherlands, and France by the author, with pport from the National Endowment for the umanities, this five-chapter book advances owledge about land banking, "defined rather oadly as public, or publicly authorized, acquisin of land to be held for future use to implement iblic land use policies" (p. 2). This descriptive ork by the chairman of the Department of City d Regional Planning at the University of nnsylvania reviews the concepts influencing land vnership and land-use policies in the United States, presents case studies of land banking as practiced in the three countries previously mentioned, and examines the potential for land banking in the United States. Practitioners of disciplines concerned with land-use problems on the fringe of both metropolitan centers and small towns and with retention of land in agricultural uses will find this book useful.

The concepts review is especially informative, starting with Plato and ending with the Grand Central Terminal case, *Penn Central Transportation Co.* v. *City of New York*. Strong concludes that we in the United States "may be moving from a [land-use] system that rewards speculation and protects landowners from losses based on public actions toward a system that defines public purpose more broadly and judges it equitable for society to retain the values resulting from its investment" (p. 39).

To assist in accommodating this changing public view, Strong carefully chose the three countries in which she studied land-bank programs. Sweden began a land-banking program in the city of Stockholm in 1904 because of a "[c]oncern about emigration [to the United States] and a desire to make homeowning possible" by reducing the cost of land (p. 48). Given its long tradition of public landownership, this was not viewed in Sweden as a revolutionary undertaking. This case is limited to the Stockholm region and how the program there has been affected by national policy, by intranation migration, by changes in lifestyle preferences, by competition from suburban towns, and by political decisions concerning lease rates and types of development.

The Netherlands was selected because the Dutch also view land as involving an element of public trust that supercedes private rights. The Dutch started land banking in 1896, in response to rapid growth in cities and the high costs associated with developing land reclaimed from the sea. Strong found "[t]he Dutch approach to land banking . . . calm, low key, and rational. For them it has worked extremely well" (p. 107). Again she describes the development of the land bank, its relation to national, regional, and municipal planning, and how various municipalities have managed their land-bank activities.

France was selected because the concepts the French hold about landownership closely parallel those existing in the United States. The French adopted their first land-bank program in 1958. A major goal was to control land prices in rapidly developing areas "by a combination of public preemption power and purchase" (p. 140). Six programs had been adopted by the time of the study, 1973/74. Four are known collectively as the Zs, the priority urbanization zone, the planned development zone, the picturesque zone, and the deferred development zone. These are joined by a farmland preservation program conducted through "[p]rivate, nonprofit organizations called SAFERs (Société d'Aménagement Foncier et d'Etablisse-

ment Rural)" (p. 172). The sixth program is conducted by regional councils, appointed bodies with legislative authority, power to collect certain taxes, and authority to make grants for purchase of land for "continued open space or for medium-term land reserves" (p. 184). Substantive detail is presented about each program and the institution designed to fund it.

Each case gives careful attention to the land acquisition process and to the way the acquired land is valued. Ten pages are devoted to the SAFER, a unique institution managed by farmers and persons engaged in agriculture and reflecting a long-term commitment by the French "to the improvement of farm productivity and to the encouragement of the family farm" (pp. 171–72). "Overall, its role is significant" (p. 244).

The author finds that in both Sweden and the Netherlands "land banking continues to be desirable on the grounds of efficiency and equity. Public ownership enables municipalities to time development . . . and to exercise control over the mix of land uses. It also assures that owners of development sites will not benefit from land sales and thus work an injustice on those landowners restricted to farming or other low-density uses" (p. 242). The programs in France are "well conceived in legal and administrative terms. . . . are in extensive u and, for the most part, worthwhile and importan (p. 244). However, the French have been unable decide "how much of a landowner's value it equitable to remove through planning decisions . [with the result that] political pressure often lea to the granting of permission to develop sites not development zones for private housing" (p. 244

When examining the potential for land banking the United States, Strong turns to the Puerto Ric Land Administration Act of 1962 and to the *Mod Land Development Code* endorsed by the Ame ican Law Institute in 1975. Both instruments a examined, and the text of each is presented as appendix to the final chapter. Strong proposes th land banking in the United States might appropi ately begin with those intensive developments th are recognized as development of greater than loc significance.

The author completed an enormous task qui well. Only the section discussing the Zs is tedio reading. This excellent descriptive work lacks ar economic analysis, a criticism regularly made t economists of studies conducted by planners.

J. Paxton Marshall
Virginia Polytechnic Institute and State Universi

Necrology

Paul H. Bebermeyer, retired professor of agricultural economics, University of Missouri, died 2 May 1980 at the age of 84.

L. C. Davis, retired farm management professor at Oklahoma State University, died 19 September 1979. He was 69.

Theodor Heidhues, University of Göttingen, died 11 November 1978 after a prolonged illness. He was 45.

Sidney Samuels Hoos, professor emeritus of agricultural and resource economics, business administration, and economics, University of California, Berkeley, and an AAEA Fellow, died 0 September 1979 in Berkeley. He was 69 years old.

Joseph M. Johnson, professor emeritus, Virginia Polytechnic Institute and State University, died 22 April 1979 at the age of 61.

William H. Nicholls, Vanderbilt University, died 4 August 1978, following a heart attack. He was 64.

Truman R. Nodland, professor emeritus, University of Minnesota, died 25 August 1979, at the age of 71 after a long illness.

W. J. "Aggie" Nucholls, associate professor emeritus, Virginia Polytechnic Institute and State University, died in March 1979, at the age of 74.

Loris A. Parcher, retired professor, Oklahoma State University, died 23 October 1979.

Percy Leo Strickland, Jr., USDA employee stationed at Oklahoma State University, died 0 June 1979.

Maurice C. Taylor, long-time member of the Department of Agricultural Economics and Economics, Montana State University, died of a heart attack 7 June 1979.

Robert M. Walsh, agricultural economist and administrative official in the Department of Agriculture, died 21 August 1979.

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Objective

The AAEA seeks to further the systematic development of knowledge of agricultural economics in order to improve agriculture and agriculture's contribution to the general economy. The activities of the AAEA include:

—publishing the *American Journal of Agricultural Economics;*
—planning and conducting two annual meetings of the membership;
—sponsoring annual awards for outstanding extension programs, distinguished teaching, and outstanding research;
—recognizing outstanding agricultural economists through a fellows program;
—supporting a literature retrieval system in cooperation with the U.S. Department of Agriculture;
—publishing periodically a biographical directory of the AAEA's members;
—supporting an employment registry for agricultural economists in cooperation with the U.S. Department of Labor.

Membership and Subscriptions

Membership in the AAEA is open to individuals having a professional interest in agricultural economics. Dues, payable at the beginning of each calendar year, are as follows: regular members, $25, senior members, $12.50, and junior members, $12.50. Senior membership is open to persons, upon written request, who are sixty-five years of age or older and have retired from active professional work. Junior membership is for students and is limited to three years; students should use application forms available from and signed by the head of the department in which they are studying. Members receive this *Journal*.

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The purpose of the *Journal* i to provide a forum for creative and scholarly work in agricultural economics. Thus, acceptable manuscript should have a relationship to the economics of agriculture natural resources, or rural and community development Contributions, methodological or applied, in the business, extension, research, and teaching phase of agricultural economics ar equally encouraged.

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All manuscripts and editorial correspondence, except as noted below, should now be addressed to the new editor, James P. Houck, Departmen of Agricultural and Applied Economics, University of Minnesota, St. Paul, MN 55108

Communications concerning book reviews and books submitted for announcement in the *Journal* should be sent to the new book review edito Ronald A. Schrimper, Department of Economics and Business, North Carolin State University, Raleigh, NC 27607

American Journal of Agricultural Economics

Volume 62 Number 5

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Harold O. Carter
Kenneth R. Farrell
John W. Mellor

Harold O. Carter

1980 Fellow

Chairman, Department of Agricultural Economics, University of California, Davis, 1970–76; Chairman of the Faculty, College of Agricultural and Environmental Science, U.C.-Davis, present.

Visiting professor, Agricultural College of Sweden, Upsalla, 1967; Center of Agricultural Economics, University of Naples, Italy, 1971; Senior Research Scholar, International Institute of Applied Systems Analysis, Laxenburg, Austria, 1976–77.

AAEA Editorial Council; associate editor, *AJAE* 1968–71. AAEA Award for Outstanding Research, 1963, 1967, 1971, 1975. President, WAEA, 1975–76.

Senior Staff Economist, President's Council of Economic Advisors, 1969–70; member, Economic Advisory Board to the Secretary of Commerce, 1973–74.

Harold O. Carter has achieved wide recognition for his research within the broad area of production economics and for his ability to focus on important public policy issues. Especially notable have been his pioneering efforts and imaginative empirical analyses pertaining to risk and variability in agricultural production, input-output applications in agriculture, production function methodology and applications, measurement of economies of scale in agricultural production, and interregional analysis and projections. While most of these studies have involved collaborative efforts, the importance of Carter's contributions is revealed by the fact that the work in each of the above areas and with various individuals has been recognized for its uniqueness and quality by AAEA or WAEA awards.

Born in Michigan, Carter received B.S. and M.S. degrees at Michigan State University and his Ph.D. at Iowa State University. He joined the faculty at the University of California, Davis, in 1958, served as chairman of his department from 1970–76, and has served on a wide range of University governing committees, including current service as chair of the faculty for the College of Agricultural and Environmental Sciences.

In his career at Davis, Carter also has made excellent contributions to teaching and has been particularly effective in his work with graduate students and in his contributions to the development of the graduate program. He was a visiting professor at the Agricultural College of Sweden, Upsalla, in 1967, and at the Center of Agricultural Economics, University of Naples in 1971.

Carter has served his profession in a variety of ways. He was a member of the Editorial Council and served as associate editor of the

Journal from 1968–71. In 1969–70 he was a Senior Staff Economist, President's Council of Economic Advisors. He served as a member of the Economic Advisory Board to the Secretary of Commerce, 1973–74 and was elected president of the Western Agricultural Economics Association, 1975–76. In 1976–77 he was a Senior Research Scholar, International Institute of Applied Systems Analysis, Laxenbürg, Austria.

Kenneth R. Farrell

1980 Fellow

Administrator, Economics, Statistics, and Cooperatives Service, U.S. Department of Agriculture, Washington, D.C., 1977–present.

Deputy Administrator, 1971–77; Chairman, Outlook and Situation Board, Assistant Administrator, Director Marketing Economics Division 1967–68; Economic Research Service, U.S. Department of Agriculture, Washington, D.C.

Associate Director, Giannini Foundation of Agricultural Economics 1969–71; Economist, Giannini Foundation and Cooperative Extension Service, Lecturer, Department of Agricultural Economics 1957–67; University of California, Berkeley.

Director 1972–74; President 1976–77, American Agricultural Economics Association.

Kenneth R. Farrell is a tireless public servant devoted to using the discipline of agricultural economics in widening service to society. Growing into increasingly demanding administrative positions, first in a university setting and then in government, he has brought a deep sense of social relevance, an instinct for workmanship, and a continuing search for improved scholarly standards to increasingly complex social problems. Operating under a set of democratic principles, his transactions with peers and subordinates are always conducted with grace and equanimity.

Born and raised in rural Ottawa, Farrell received a bachelors degree with honors from Ontario Agricultural College, University of Toronto, in 1950, taught agriculture in North Dakota in a veterans' rehabilitation program for two years, then attended Iowa State University, receiving the M.S. and Ph.D. degrees in agricultural economics. In 1957, he joined the staff of the University of California at Berkeley.

At California, he served for a decade in various administrative, research, teaching, and extension posts, including Fulbright Lecturer in Agricultural Economics at the University of Naples and an assignment with the National Commission on Food Marketing. During this period, he made major contributions to the application of economic theory and statistical methods in the analysis of marketing problems of agricultural commodities. The results of these analyses were used extensively in the design and management of federal and state marketing orders for California commodities. Throughout this ten-year period, Farrell was heavily involved in public education programs of the University. He was regarded as an excellent teacher and com-

municator, and was recognized for his integrity, objectivity, intellectual leadership, and professional vigor in research and extension.

Beginning in 1967, Farrell has held a succession of increasingly responsible and complex administrative posts, all related to agricultural economic research, statistics, and information programs. As Associate Director, Giannini Foundation, he was responsible for the development of program planning and coordination mechanisms involving research on two campuses and extension on three campuses of the University of California.

From the University of California, he moved to the USDA where he has held a succession of administrative positions—Director, Marketing Economics Division; Chairman, Outlook and Situation Board; Assistant and Deputy Administrator in the former Economic Research Service; and Administrator, Economics, Statistics and Cooperatives Service. In those positions, Farrell has made major contributions to the development and strengthening of economic research and outlook programs in the department. He has recruited competent staff and research leaders, set consistently high standards of professional excellence, dedicated the agency to serving the public interest. He has insisted upon integrity and objectivity in research and statistical programs and provided intellectual leadership and vision in the long range planning and development programs.

Farrell has contributed significantly to the development of our professional societies. He was a member of the Board of Directors of AAEA for six years, serving as its president in 1976–77. During that period he provided effective, forward-looking leadership, as evidenced in the creation of an Outstanding Public Policy Award, the development of organized symposia as an integral part of the AAEA annual meeting, strong encouragement and support of a public policy institute, and the encouragement and support of AAEA sponsorship of special workshops and symposia to address major public policy and professional issues. His presidential address, "Public Policy, the Public Interest, and Agricultural Economics," provided useful insights into the status of policy research in the profession and contributed to a resurgence of interest and activity in public policy research and extension in the profession.

In addition, he has chaired the contributed papers competition at the three most recent meetings of the International Association of Agricultural Economists. That activity illustrates a way in which Ken Farrell leaves his mark. Spanning a decade, the role of the contributed paper in improving the scientific vigor and social relevance of international discussion of food and agricultural problems has grown ever larger and more effective.

There is perhaps no better indication of Farrell's approach to his chosen fields of interest than the following excerpt from his presidential address to this Association in 1976: "We should broaden our professional perspectives, cultivate new clientele and professional alliances, recast and reorder our agenda, and experiment with modified and new institutional arrangements. In so doing, we could better address emerging public policy issues and better serve the public interest concerning food and agriculture."

John W. Mellor

1980 Fellow

Director, International Food Policy Research Institute, Washington, D.C.
Professor, Department of Agricultural Economics, Cornell University, 1954–77.
Chief Economist and Associate Assistant Administrator for Policy and Development Analysis, USAID, Department of State, 1975–77.
Editorial Council, *Journal of Farm Economics*, 1961–64; *Human Organization*, 1965–70.
American Agricultural Economics Association Awards: Outstanding Published Research Report, 1968; Publication of Enduring Quality, 1978.
Visiting Professor, Balwant Rajpat College, India, 1959–60; Indian Agricultural Research Institute, 1964–65; American University Beirut, 1968.
Member, American Academy of Arts and Sciences.

John W. Mellor is one of the leading scholars in the economics of agricultural development. He and his students have made important contributions in research, teaching, and the implementation of development programs both in the United States and overseas. His publications are widely read. He has given high priority to the growth of agricultural economics as a discipline in developing countries. His energy, optimism, and enthusiasm are infectious and redound throughout his work.

Born in Paris, France, Mellor grew up in Vermont and operated a sizeable poultry enterprise while in high school. He completed a bachelors degree in agriculture at Cornell University in 1950, held a Fulbright fellowship at Oxford University in 1951–52, and completed his doctorate at Cornell in 1954.

Mellor began his career as a faculty member at Cornell by teaching the introductory undergraduate course in agricultural economics to more than 300 students each year. Development economics was introduced in this course, even though the primary emphasis was given to the reasons various types of agricultural production occur where they do throughout the world.

He organized Cornell's first formal course on the economics of agricultural development after spending eighteen months as a visiting professor at a small agricultural college near Agra, India. His energy and enthusiasm for work in this field was a major factor in a successful effort to obtain funding for a teaching and research program in international agriculture at Cornell. Mellor was appointed to one of the first professorships in international agriculture in 1962. He served as associate director of the university-wide Center for International Studies 1961–66. He also held courtesy

appointments in the Departments of Economics and Asian Studies and was director of the Program on Comparative Economic Development.

Mellor's first book, *The Economics of Agricultural Development,* grew out of his experience as a teacher and research scholar and his work with graduate students. Widely used, it has been translated into French, Spanish, Portuguese, Arabic, and Vietnamese. It received the AAEA Award as a publication of enduring quality in 1978. He is the author of two other books, *Developing Rural India: Plan and Practice* (with Weaver, Lele, and Simon) in 1968, and *The New Economics of Growth—A Strategy for India and the Developing World,* 1976. He is editor of the volume, *India: A Rising Middle Power,* 1979, and he has made contributions to eleven other books and collections of readings. He has published articles and notes in nine major journals including the path-breaking paper, "The Role of Agriculture in Economic Development," in collaboration with Bruce Johnston. This article, first published in the *American Economic Review,* has been reprinted, notably in the AEA *Readings in the Economics of Agriculture.*

The commitment to publication and to share the results of research has been transferred to those with whom he has worked. Many of Mellor's students have been the sole author of a monograph, bulletin, or book based on thesis research. No study goes unreported. Perhaps most important, he encourages continued professional growth and involvement in the discipline wherever former students are located.

Mellor has had wide experience overseas, though most of his own research has been associated with work in south and southeast Asia. He has been a member of the Board of Directors of International Voluntary Services since 1962. He also has been a member of the National Screening Committee, Foreign Area Fellowship Program in Asia, and chairman of the Mekong Development Panel of the Asia Society; and a consultant to the World Bank, FAO, and the Rockefeller Foundation.

After serving as director of a number of research contracts funded by USAID at Cornell University, Mellor took leave in 1975 to be chief economist and associate assistant administrator for policy development and analysis at USAID. In 1977, he accepted the challenge of the directorship of the International Food Policy Research Institute in Washington. He was elected to membership in the American Academy of Arts and Sciences that year as well.

John Mellor has had an important impact on teaching, research, and scholarship in international agriculture. He has a strong allegiance and concern for rural people and their key role in the development process. His interest in policy and his analyses reflect a respect for original data and the need for firsthand knowledge from the field.

Presidents, 1910–81

1910–12
William J. Spillman

1913
George F. Warren

1914
Daniel H. Otis

1915
Andrew Boss

1916
Harcourt A. Morgan

1917
Henry W. Jeffers

1918
George A. Billings

1919
John R. Fain

1920
Henry C. Taylor

1921
Walter F. Handschin

1922
Benjamin H. Hibbard

1923
Thomas P. Cooper

1924
Edwin G. Nourse

1925
Milburn L. Wilson

1926
Thomas N. Carver

1927
John I. Falconer

1928
Lewis C. Gray

1929
H. E. Erdman

1930
Harold C. M. Case

1931
Oscar C. Stine

1932
John D. Black

1933
Howard R. Tolley

1934
William I. Meyers

1935
Waldo E. Grimes

1936
Joseph S. Davis

1937
Oscar B. Jesness

1938
Ernest C. Young

1939
Irving G. Davis
Foster F. Elliott

1940
Hugh B. Price

1941
Murray R. Benedict

1942
George S. Wehrwein

1943
Sherman E. Johnson

1944
Eric Englund

1945
Lawrence J. Norton

1946
Frederick V. Waugh

1947
Asher Hobson

1948
William G. Murray

1949
Oris V. Wells

1950
Warren C. Waite

1951
Forrest F. Hill

1952
George H. Aull

1953
Harry R. Wellman

1954
Thomas K. Cowden

1955
Joseph Ackerman

1956
Karl Brandt

1957
H. Brooks James

1958
Harry C. Trelogan

1959
Raymond G. Bressler, Jr.

1960
Willard W. Cochrane

1961
William H. Nicholls

1962
Bushrod W. Allin

1963
George E. Brandow

1964
Lowell S. Hardin

1965
D. Gale Johnson

1966
Kenneth L. Bachman

1967
Lawrence W. Witt

1968
C. E. Bishop

1969
Harold F. Breimyer

1970
Dale E. Hathaway

1971
Jimmye S. Hillman

972
Vernon W. Ruttan

973
Emery N. Castle

1974
Kenneth R. Tefertiller

1975
James Nielson

1976
James T. Bonnen

1977
Kenneth R. Farrell

1978
R. J. Hildreth

1979
Bernard F. Stanton

1980
Richard A. King

1981
Luther G. Tweeten

Luther G. Tweeten

1980–81 President

Regents Professor of Agricultural Economics, Oklahoma State University.
Visiting Professor, Stanford University, University of Wisconsin-Madison.
Board of Directors: AAEA, 1969–72; Bread for the World 1980–83.
Chairman: AAEA Contributed Papers 1972; Economic Statistics Committee 1976–78; Oklahoma State University Faculty Committee 1970–72.
Consultant: Harvard Development Advisory Service; U.S. Senate and House committees on agriculture; U.S. Department of Agriculture; Oklahoma Department of Education; Joint Economic Committee of Congress; National Commission on Employment and Unemployment Statistics.
Awards: Distinguished Alumnus, Waldorf College; Outstanding Research, Western Agricultural Economics Association.

Luther Tweeten was born in 1931 at Las Vegas, New Mexico. He grew up on a farm in northern Iowa and graduated from Lake Mills High School in 1950. After attending Waldorf College for two years, he entered Iowa State University in 1952 and received a B.S. degree in agricultural education in 1954. Following two years as a Special Agent in the Army Counter Intelligence Corps, he entered Oklahoma State University in 1956, where he received his M.S. degree in agricultural economics under Burl Back in 1958.

He returned to Iowa State University to work under Earl Heady and received the Ph.D. degree in agricultural economics in 1962. Tweeten advanced from assistant professor in 1962, to associate professor in 1963, to professor in 1965, and to Regents Professor in 1972, in the Department of Agricultural Economics at Oklahoma State University. He was visiting professor at Stanford Universit in academic year 1966–67, and at the Institut for Research on Poverty at the University c Wisconsin-Madison, 1972–73.

His research emphasis has been on prob lems of regional and national economic deve opment, the economics of human resource: and public policy for agriculture. Of his fou books and over 200 national journal article and published papers, perhaps the best know are *Foundations of Farm Policy* and *Micro politan Development*, the latter coauthore with George Br. kman.

He has taught c rses in research metho ology, mathematical economics, rural deve opment, and farm policy. He is a member six professional societies and three honora fraternities.

In 1964, he was granted an award by tl American Farm Economics Association to a

tend the international meeting of agricultural economists at Lyon, France. In 1970, he received the Distinguished Alumni Award from Waldorf College in Forest City, Iowa. He received the award for "outstanding published research" from the Western Agricultural Economics Association in 1972. He was major advisor to graduate students who won the award for "best thesis" given by the AAEA in 1970 and in 1975. Tweeten has been called to serve as an expert witness before congressional committees numerous times.

He is married to the former Eloyce Hugelen, and they have four children.

Macroeconomics in Crisis: Agriculture in an Underachieving Economy

,uther G. Tweeten

'he American economy performs like an auto ngine whose radiator is choked with lime de-osits. Some time ago, it was discovered that dding generous amounts of tap water to the adiator permitted high power output without ›verheating. As the years went by, however, ime deposited in the radiator by the tap water educed cooling capacity—tap water had to be dded continuously for adequate engine per-ormance even under normal loads on level ighways. Deposits finally built to the point /here nearly all agree that something has to be one to restore power to this basically sound, ut occluded, engine. One recommendation is ɔ use a high pressure radiator cap for increas-ıg engine performance without continually dding water. But the concern is that some-hing will burst under the pressure. Another ecommendation is to remove the radiator and ook out the lime deposits. The drawback is ›rotracted engine downtime.

These are basically the dilemmas and op-ions facing macroeconomic policy today. Per-ormance of the economy as apparent in high ıflation and unemployment rates, in slow real rowth, and in a weak dollar in international xchange has reached crisis proportions. :conomists and the public are convinced the conomy is capable of better performance, but ıere is no concensus about how to restore igor to the underachieving economy.

My thesis is that misguided macroeconomic ıeory and practice have created a chronically nderachieving national economy. Just as the conomic debilitation wrought by misguided ›olicies has been slow to emerge, it will be low to dissipate. The underachieving econ-›my is a degenerative malaise transcending he current recession. The economy will be slow to respond to remedial policies because underachievement is rooted in attitudes and institutions which change slowly.

The underachieving macroeconomy is the single most important characteristic of the economic environment facing agriculture in the 1980s. I briefly review evidence of the crisis and the contribution of macroeconomic theory and practice to the crisis. I then exam-ine two directions macroeconomic policy could take to begin to restore health to the economy. A principal objective of the paper, dealt with in the final sections, is to trace im-plications to the farming industry of (*a*) an underachieving national economy in the 1980s, and (*b*) alternative policies likely to be pursued to restore economic vitality.

The Gathering Crisis

The crisis in macroeconomics is evident in fact and logic. Society seeks equity and efficiency from an economic system. The dis-tribution of income in the United States has remained remarkably stable since World War II, and we look to measures of efficiency such as productivity and per capita income for signs of economic progress. The following indi-cators reveal deteriorating national perfor-mance since the 1960s:

	1960s	1970s	1979
	(annual average, %)		
Unemployment rate	4.8	6.2	5.8
Inflation rate in CPI	2.2	6.5	13.3
Labor productivity rate (increase in output per hour in the private business sector)	2.8	1.3	−1.0
Real income growth rate (increase in real disposable personal income per capita)	2.7	2.2	−1.0

(Source: Council of Economic Advisors, pp. 229, 237, 246, 259.)

Average rates of unemployment in the 6%

'resident's address.

Luther G. Tweeten is Regents Professor, Department of Ag-ricultural Economics, Oklahoma State University.

Journal article of the Oklahoma Agricultural Experiment Sta-tion.

Comments of Leo Blakley, Bruce Bullock, and Daryll Ray were helpful; the author bears sole responsibility for deficiencies herein.

range are hardly cause for approbation, but of principal concern is the high and accelerating rate of inflation coupled with slow and declining rates of growth in labor productivity and real income per capita.

Proximate causes of the economic slowdown are multiple: (*a*) rising energy costs because of OPEC price increases; (*b*) increased spending on pollution control, health, and safety; (*c*) entrance into labor force of inexperienced workers, especially youth, females, and minorities; (*d*) realignment in terms of international trade to correct for previously over-valued dollar; (*e*) shift from agriculture and manufacturing to service industries with low productivity growth; (*f*) depletion of natural resources including oil, iron ore, and soil; (*g*) increased tax burden of social security and other social programs; (*h*) rising minimum wage; (*i*) declining high payoff investment opportunities; and (*j*) low savings and investment rates.

Rising energy prices (*a*) are a convenient scapegoat for deteriorating performance but only two to three percentage points of the 13% increase in consumer prices in 1979 were attributed to OPEC price increases (Council of Economic Advisors, p. 162). The economies of Japan and West Germany, for example, are strong despite greater dependence than the United States on high-priced imported energy. Environmental programs have absorbed resources and are of value. If their value were included in conventional national accounting for output of goods and services, the performance of the economy might be raised from a grade of "fail" to "low pass." Entrance of inexperienced workers into the labor force and realignment in terms of trade also caused economic performance to falter. The important point, however, is that the retarding influence of items (*a*)–(*d*) has crested—these factors will arrest the growth rate less in the future than in the past.

Economic progress contains the seeds of its own slowdown, as shares of income-elastic but low-productivity-growth service industries become prominent relative to high-productivity-growth industries such as agriculture, and as natural resources become depleted. Elements (*e*) and (*f*) retard growth in the long run, are expected, and are not the basis for classifying the secular decline in growth as economic underachievement. They do not account for the poor performance of the United States relative to other advanced capitalistic economies that possess few natural resources.

Therefore, we turn to factors (*g*)–(*j*) fo sources of chronic economic underachieve ment. Sluggish investment and savings mea slow capital formation at a time when capita formation is desperately needed to buil energy-producing capacity, more jobs, an more output per worker. The savings rat dropped cyclically from 7.4% of disposabl personal income in the 1970–75 period to 3.3% in late 1979 (Council of Economic Advisors p. 228), but for decades propensities to sav and invest have not declined secularly in thi country. I regard no increase in such propen sities as underachievement in a society ex periencing a growing surplus of production i excess of basic needs, increasing depreciatio of capital stock, and keen competition fron abroad. Propensities to save and invest ar low in relation to those of other advanced in dustrialized countries.

Average annual plant and equipment in vestment increased only 2.6% annually in rea terms 1968–78, compared to 6.2% annually i the previous decade. Capital investment i manufacturing as a percentage of gros domestic product 1960–76 averaged only 9.1% in the United States, compared to 28.8% i Japan, 15.9% in West Germany, 14.7% i Canada, and 13.5% in the United Kingdon (Committee for Economic Development, p 3).

The United States invests a smaller share o national income in research and developmen than other leading industrial nations, and pat ent application rates are falling. Excess-profit taxes, government regulations, and othe forces frequently direct investment into ven tures with low social rates of return or dis courage investment in ventures with high so cial rates of return. Investment level and profitability cannot be separated; i.e., the lack of profitable and productive capital investmen opportunities reduces the magnitude of sav ings and investment. Ruttan (p. 896) stresse the interaction among growth-inhibiting ele ments, noting that inflation reduces growth i labor productivity. Finally, it is well to not that growth dividends from unleashing factor (*a*)–(*d*) will be absorbed by demands for capi tal to meet needs for energy, social welfare fo an aging population, and national defense.

Disenchantment with Neo-Keynesian Macroeconomic Theory

Disappointing levels of saving, investment, efficiency, and hence of economic progress,

ive roots in the neo-Keynesian (NK) macro-conomic paradigm that has guided this nation r over three decades. Neo-Keynesian eco-omics holds to Keynesian precepts of a hort-run equilibrium at less than full em-oyment, capacity for short-run tradeoffs be-veen unemployment and inflation, and for a overnment role in monetary-fiscal policy to imulate aggregate demand in depressions id severe recessions when planned savings ceed planned investment. But NK econom-s adds to these Keynesian precepts the opositions that advanced capitalistic nations e chronically prone to (*a*) high unemploy-ent, (*b*) economic instability, and (*c*) increas-g concentration of resources and wealth. he underlying causes of these three phenom-a include unpredictable "animal spirits" at shift nationwide spending moods from otimism to pessimism, and big business that ploits labor and the consumer—tendencies hich must be countervailed by perennial onetary-fiscal stimulation of aggregate de-and, by social legislation to redistribute ealth and protect the worker and consumer, id by formation of politicoeconomic collec-ves to promote economic democracy through paternalistic government.

The neo-Keynesian economic paradigm de-rves much blame for an underachieving na-onal economy. Shortcomings of the NK par-ligm discussed in the next section call for w directions in macroeconomic theory and actice. But neither economists nor the pub- agree whether the call is to the right or to e left.

ost-Keynesian Macroeconomics

ost-Keynesian economists are united in eir disenchantment with neo-Keynesian acroeconomics. Their critique and prescrip-on for a new paradigm vary widely as appar-nt below.

ight-Wing Macroeconomics

ight-wing post-Keynesian macroeconomics, nlike left-wing post-Keynesian macroeco-omics to be discussed later, acknowledges tle debt to Keynes, although many right-ving adherents concede that Keynesian eco-omics is applicable to a depression. Right-ving macroeconomics contains several ranches including natural rate and rational xpectations schools—largely monetarist in orientation, and a supply-side school—largely neoclassical in orientation.

Natural rate and rational expectation economics. In Keynes' statement that "It is probable that the general level of prices will not rise very much as output increases, so long as there are available efficient unemployed resources of every type" (p. 300), he recognized the trade-off between unemployment and inflation. Following quantification of the relationship by Phillips, the notion that it was possible to sustain low levels of unemployment by tolerating inflation became widely accepted.

Protests to the position emerged, however. The case began to build that workers, given time, react to real rather than money wages (cf. Dernburg and McDougall, pp. 283–5, 393; Morley). The long-term Phillips curve was perceived as vertical at the natural rate of unemployment. The long-term aggregate supply of national output was viewed as vertical, or even sloping upward to the left as a function of the inflated general price level. To be sure, monetary-fiscal stimulus raises nominal demand for national output, and the resulting rise in the general price level induces workers and other suppliers to increase output. But suppliers discover that the increase in the demand price is mostly nominal, not real, and increase their supply price for a given output. The resulting higher nominal aggregate supply curve intersects the nominal demand curve at a higher general price level but approximately at the former equilibrium quantity Q. The economy tends to overreact and temporarily moves to a lower output than Q. Termination of the monetary-fiscal stimulus may return both the price level and output to the initial level but not without substantial trauma in the form of high unemployment and underutilized capacity until equilibrium at Q, the natural or equilibrum output, is restored. This inflation cycle of expansion and stabilization behaves much like the traditional business cycle. (See Morley for an extended discussion.)

The rational expectations hypothesis, originally associated with Muth and applied broadly to macroeconomics by Lucas and Sargent, as well as by others, holds that decision makers adjust expectations for the impact of public policy so as to remove systematic error in their predictions. In the case of stimulation of aggregate demand by fiscal-monetary policy, decision makers learn to anticipate that the initial increase in the marginal value product of labor and in aggregate demand is

pecuniary and will be attended by an upward shift in nominal wage demand by workers and in aggregate nominal supply. After the learning experience of first increasing and then decreasing output in response to monetary-fiscal stimulus before reaching a new equilibrium at a higher general price level but at the natural rate of output Q, suppliers learn to shift nominal supply upward at the same rate as nominal demand. This short-circuits real impacts of monetary-fiscal stimulus and real output holds at Q. Monetary policy loses its intended impact; real demand and supply, output, and employment are unchanged by public policy, whatever the inflation rate. Although unanticipated policies have real impacts, they are not useful government policy because their impact, if repeated, is anticipated and hence solely pecuniary.

Those who have witnessed farm commodity cycles repeated for decades are skeptical about the rational expectations hypothesis. Nevertheless, a learning process occurs with successive stimulation of aggregate demand, which in turn generates the inflation cycle. This cycle of expansion and contraction in output under the natural rate hypothesis becomes less pronounced as learning proceeds—behavior consistent with the rational expectations hypothesis.

Supply-side economics. The nation blundered into the Great Depression blindly following Say's Law that supply creates its own demand; the nation blundered into stagflation by blindly following Keynes' Law that demand creates its own supply. Many students first encountered economics defined as the science of allocating scarce means among unlimited wants to satisfy those wants as fully as possible. NK macroeconomics would allocate limited wants among unlimiting means to utilize those means as fully as possible. Except in the short run, the concept of limited wants and unlimited means fails to square with even casual observation of reality.

In the traditional Keynesian model, another dollar of investment or government spending adds $1/s$ dollars to income, where s is the marginal propensity to save. As s approaches zero, the multiplier approaches infinity. Small doses of autonomous investment are required to boost national income in an economy where s is small. To make the economy responsive to stimulative policies by making s small, spending became a virtue and thrift a vice. The allure of the "free lunch" and the sanctioning of massive government spending to stimula demand through consumption, as opposed stimulating supply through investment (whic requires deferred gratification), made ne Keynesian remedies irresistible. The prope sity to save s could be made small, for exam ple, by making social security universal an financed by taxes rather than by actuarial sound investments. The problem is that as becomes small, all is consumed that is pr duced and growth comes only as inflated, n real, dollars.

Sobering vignettes from economic theo emphasize the importance of supply-side ec nomics. The Harrod-Domar tautolog showed that the rate of growth of real income was a product of the output-capital rat (efficiency) g and the propensity to save s, i.e $r = gs$. This conclusion that a high rate savings is associated with a high real rate economic growth is contrary to the NK mod and received little attention from ma roeconomic textbooks, politicians, and th public because it called for a return to deferre gratification and the dismal science of ec nomic scarcity.

Supply-side economics recognizes that u used capacity and unemployment will b present in a "full employment" economy. A issue is whether the unutilized capacity profitable to operate at the margin. In keepin with neoclassical theory, supply-side econon ics emphasizes the importance of examinin whether it pays employers to hire unemploye workers and whether workers hired und public employment or other NK-type pr grams contribute more to real output tha would alternative uses of the resources.

Neo-Keynesian prescriptions have stru tural impacts on supply. Persistence Keynesian prescriptions slowly alters institu tions and attitudes in a manner that robs th market economy of savings, investmen flexibility, and other features critical for ec nomic progress. Firms in an atomistic, com petitive industry find it difficult to pass inflate costs to other industries and consumer Firms possessing much bargaining power in highly concentrated industry and laborers i powerful trade unions can more readily pa on costs to the next link in the market chai Minimum wage laws, unemployment insu ance, collective bargaining legislation, an other measures established by government t provide built-in economic stabilizers fc aggregate demand also provide a framework c

nabling-legislation for growth of monopoly in ie form of big labor and big business which se market power to pass rising costs to conumers.

But even General Motors cannot pass all osts to consumers because of competition om foreign firms. In world perspective, ajor U.S. industries are in many cases omistically competitive, and scope for onopolistic exploitation is limited without ollusion of government in the form of trade arriers. Major American industries have lost heir world dominance partly because of eo-Keynesian macroeconomics. In part beause of the growth of organized labor and its emonstration effect on other workers, and in art because major U.S. industries operate in highly competitive world market where risg labor costs cannot be passed to consumrs, labor has increased its share of firm reeipts. The result is less investment in capital increase worker productivity and expand bs. Federal double-taxation of corporate rofits and allowance for depreciation at less an replacement costs further erodes capital rmation in an inflationary economy.

Special interest politics has played a role in tting "full employment" targets that cannot sustained because of intolerable inflation. mphasis on raising aggregate demand by imulating consumption has attracted a host political special interest groups to share vernment largess. Government has become e politics of distribution. The distribution s been to those possessing political power d not necessarily to the poor or disadvanged. Critics argue that economic democracy ks government to perform far more than it s capacity to deliver. Before goods can be stributed, they must be produced.

Right-wing charges of neo-Keynesian conbutions to an underachieving economy go , but more positive dimensions of right-wing onomics exist. The right-wing argues it is in ne with wants of people for personal freem while at the same time funneling the selfterest of impersonal man to serve the public terest through the invisible hand of the comtitive market. Right-wing economists point the economic success of the essentially free nterprise economies of Singapore, Hong ong, Taiwan, and, prior to recent times, the nited States.

American agriculture of today provides one the best sector examples of the right-wing odel. The competitive farming industry plows back 30% of its income into capital investment, whereas the nation as a whole invests about 10% of national income. Farm labor productivity perennially increases at approximately 6% annually, while nonfarm labor productivity has stagnated. Farmers account for only 3% of national income but supply over one-fifth of all exports. Farming industry performance is unparalleled for contributing to low domestic food costs, export earnings, and redistribution of income from high income to low income consumers and taxpayers.

Left-Wing Macroeconomics

Left-wing post-Keynesian economists subscribe to no common paradigm (see Croity and other articles in the series). However, leftwing macroeconomists more or less accept the Keynesian and neo-Keynesian precepts and prescriptions listed in the previous section. In mildest form, left-wing macroeconomics merely adds to these the need for a "high pressure cap on the overheated radiator" in the form of wage and price controls. More extreme forms of left-wing macroeconomics call for government ownership of industry and a centrally planned economy.

History provides compelling evidence that large, complex economies cannot be centrally planned and administered with acceptable levels of efficiency, that price and wage controls are unworkable in all but the short run, and that socialized industry rarely operates as efficiently as private industry.

More workable are alternative forms of left-wing macroeconomics that reject both the neo-Keynesian ideology of monetary-fiscal pump priming for all seasons and the conspiratoral views of industry exploiting labor. In the successful economies of West Germany, Japan, Sweden, and Norway, government plays a major, paternalistic role in managing (but not centrally planning) the economy, reconciling labor-management conflicts, and redistributing wealth. Labor and industry cartels are allowed, even encouraged. Industry and labor are concentrated into so few entities and each has such a large impact on the nation that each holds itself (or is held) accountable to the public at large for its price and wage actions. National priorities for wages, output, and prices are worked out in negotiations among industry, labor, and government. Cooperation among these public and

private power centers is also commonplace in research and development of new products and markets as well as other endeavors not well suited to private investment alone because of risk, externalities, and economies of size. Such managed economies seem to perform well only in countries characterized by a highly industrious labor force in an atmosphere of mutual trust between labor and management. Applying the above left-wing strategy to the United States is fraught with peril because powerful collectives would be formed which could go dangerously out of control in a heterogenous nation with the tradition of an adversary relationship between labor and management.

The Untenable Middle Ground

The most notable distinction between successful economies of the right and left is whether they use competition or other forces to channel self-interest to serve the public interest—each type of successful economy exercises monetary-fiscal restraint and control over special interest groups. The latter probably makes possible the former; this is, control of economic collectives restrains cost-price inflation, and control of political collectives restrains demand-pull inflation.

The U.S. economy is in an unstable position between the left and right models. Its political and economic collectives are large enough to aggrandize themselves at the expense of the general public but small enough to escape accountability. Because the United States gets the worst of both worlds, economic performance can improve by moving toward the best of either the right-wing or left-wing post-Keynesian economic models.

Neo-Keynesian economics has become something of a drug habit which, despite failure to produce highs anymore, is difficult to foresake because of traumatic withdrawal symptoms. Large numbers of people and the politicians who represent them have a stake in continuing the "habit" despite the counsel of post-Keynesian economists. Even in the unlikely event of a sharp turnaway from neo-Keynesian prescriptions, the legacy of high inflation and unemployment, slow real income growth, and/or a weak dollar likely will persist through the 1980s. At issue is how an underachieving economy and a left or right turn in macroeconomics will affect the farming indu try.

Implications for the Farming Industry

Once farmers prospered under national boor because of a relatively high income elastici of domestic food demand and easy credit a sociated with business expansion. No domestic demand is of lesser importance- nearly three-fourths of the growth in demar for farm output comes from foreign market Once a strong labor market in the metropol was required to absorb excess farm labor; no there is little excess farm labor. (Gardner [14] found that local off-farm earnings so cri cal to farmers are not highly sensitive to n tional business conditions.) Once farming i dustry economic fortunes were tied to produ markets as influenced by business cycles; no such fortunes are more closely tied to inp prices as influenced by government-induce inflation cycles.

Some effects on the farm sector of an u derachieving economy are clearly unfavorabl others are favorable. Direct effects of a turn the right or left in macroeconomic theory ar policy may be massive, but whether they w be favorable or unfavorable in the short run not easily predicted.

Favorable Impacts of an Underachieving Economy

Favorable impacts for the farming indust include a faster rate of growth in export d mand, more elastic total demand, and less d mand for structural changes.

While growth in demand for some far products, such as beef with a relatively hig income elasticity of demand, will be slowe on the whole the response of farm output d mand to real income is now too low to be major concern. Of greater importance is th weak dollar, making our farm products a ba gain in world markets, and causing exports be the major source of the growth in demand As the major efficient sector of the econom where productivity has been kept high ar comparative advantage intact, the farming i dustry by virtue of its export position stands gain from mismanagement of the economy.

The fast-growing foreign demand for farm ıtput coupled with a slow-growing domestic conomy may turn the dynamic farming indusy into a growth industry—it may grow faster an industry as a whole in the 1980s. The rming industry may contribute a larger share national income in 1990 than in 1980.

Up to three-fourths of the growth in demand r farm output is expected to be from foreign urces in the 1980s compared with half in the 60s. The growing weight of exports in deand for farm output from 15% in 1965, to % in 1979, implies a 50% increase (from −.4 −.6) in total elasticity of output demand suming a domestic price elasticity of −.2 d a foreign elasticity of −1.5 in each year. Growing farm exports coupled with highly astic domestic alcohol fuel outlets for farm mmodities tend to make total demand for m output at "floor" prices less inelastic in e short run and elastic in the long run. The plication of stronger and more elastic deand for farm output is reduced need for govment loan, deficiency payment, and proction control programs to support the level farm product prices and incomes. Such poles would be in keeping with the market entation of right-wing post-Keynesian economics. Commodity reserve programs to bilize markets may become more important cause of growing but highly volatile export rkets.

Farms needed to grow in size at the real rate 5% annually in the past three decades in ponse to technology and the opportunity st of labor. Real nonfarm income per capita wing at (say) 1% per year rather than 3% ves two percentage points off the required wth in the scale of farm firms to "keep up h the Joneses." If labor-saving technology also forthcoming at a slower rate in an unachieving economy, farmers will get a welne breather from the adjustment treadmill the 1980s.

favorable Impacts of an Underachieving onomy

e principal unfavorable impact on the farm nomy of an underachieving nonfarm economy comes from inflation as (*a*) factor markets pond more quickly and fully to national ation than product markets, causing a t-price squeeze, and (*b*) immediate costs of land purchases rise whereas returns are deferred, causing a cash-flow squeeze.

Cost-price impact. In the 1980s, national inflation clouds optimism for rising real prices received by farmers from my projection that farm output demand growth will exceed supply growth rate due to productivity. Farmers have no immediate means to pass inflated input prices to the next link in the production-marketing chain as can imperfectly competitive input supply and product-marketing firms.

In a recent study (1980a) I found that for the 1963–77 period, inflation pass-through is complete in one year from retail food demand down to the farm level—each 1% increase in the general price level is associated with a 1% increase in nominal demand at the farm level. The situation is more complex on the supply side. Each 1% increase in the general price level is associated with an approximate 1.4% increase in prices paid by farmers, shifting the long-run nominal supply curve for farm output upward by 1.4%. Short-run inflation pass-through averaged 70% in the 1963–77 period; that is, each 1% increase in prices paid by farmers caused by inflation was associated with only a 1 ÷ 1.4 = .7% increase in prices received by farmers. Farmers restrain input use and output until eventually their buying power is restored in a pattern depicted by Tweeten and Griffin.

Cash-flow impact. Judging by net income per farm from all sources, by net worth per farm, by rates of return on farm equity capital versus returns elsewhere, and by firm failure rates, commercial farmers have on the average enjoyed robust financial health since 1960 (Tweeten 1979, pp. 53–61). However, the favorable average indices of the farming industry poorly reflect the situation faced by beginning or expanding family farms experiencing inflation-caused cash-flow problems.

Durable assets, principally real estate, interacting with inflation are the source of the cash-flow problem. The conceptual framework developed elsewhere (Tweeten 1980b) begins with the formula for the present value of an acre of farmland P_o:

$$(1) \qquad P_o = \int_{t=0}^{\infty} \frac{R_o e^{(i + i' + \epsilon)t}}{e^{(\alpha + i)t}}\, dt = \frac{R_o}{\alpha - i' - \epsilon},$$

where R_0 is after-tax net rent per acre in the initial period 0, i' is the before-tax real rate of increase in rents, i is the rate of national inflation, α is the desired real rate of return on land, ϵ is the rate of increase in net rent due to the tax advantage on farmland versus that on alternative investments, e is the base of natural logarithms, and time t goes from the initial period 0 to infinity. The discount rate (nominal total rate of return) is $\alpha + i$. In a well-functioning market, the capitalized present market value of an acre of farmland is $R_0/\alpha - i' - \epsilon$, the current rate of return on investment in farmland is $\alpha - i' - \epsilon$, and land rents and values increase at the rate $i + i' + \epsilon$.

Conceptual and empirical considerations of the model provide additional insights:

(*a*) The value of ϵ is so small at inflation rates likely for the 1980s that it will have a minor impact on land rents and returns; hence ϵ is ignored below (Tweeten 1980c).

(*b*) If rents are expected to increase exactly at the inflation rate ($i' = 0$), then land is capitalized at the desired real rate of return α and the initial and continuing current return on land is α. This principle constitutes the foundation for the cash-flow problem engendered by inflation, i.e., the current rate of return on farmland is invariant to the inflation rate! If $\alpha = .04$, or 4%, the land price is twenty-five times net rent, and the current return on land is 4% of the inflation rate. The long-term mortgage interest rate is the real rate of interest plus the inflation rate, hence inflation defers returns and inflates immediate costs. If inflation is 9% per year, nominal capital gain is 9%, which, together with the current return of 4%, brings total return to 13% per year. However, the real return is only 4% per year because the inflation in land values and rents does not add to buying power.

The mortgage interest rate is the real rate of interest, approximately 3%, plus the inflation rate i. An inflation of 9% means a mortgage interest rate of 12% which, coupled with current returns of 4%, leaves a cash flow deficit of $12 - 4 = 8\%$ of farmland value under a perpetual mortgage. In contrast, in the absence of inflation, the current return of 4% and mortgage interest of 3% leaves a cash flow surplus of 1%, excluding principal payments.

(*c*) Expected real increases in land rents ($i' > 0$) change the capitalization rate and current return on land to $\alpha - i'$, whatever the value of i and with farmland taxed at the same rate as alternative investments in response t inflation. If the desired real rate of return o land is = .04, or 4%, if land rents are expecte pected to increase at a real rate of $i' = .02$, 2% per year, and if land returns are taxed the same rate as returns from other inves ments, then land price is fifty times rent ar the initial rate of return on land is 2%. Usi Melichar's terminology (p. 109), farmland b comes a "growth stock" when $i' > 0$ and re capital gain accrues at the rate i'. If inflation 9% annually and with the above parameter the nominal capital gain is 9%, real capital ga 2%, and current return 2%, for a total annu return of 13%. Again, real return is only 4% percentage points each of current earnings ar real capital gain) because the 9% capital ga induced by inflation represents no increase buying power of land. With a 2% current r turn and 12% mortgage interest rate, the cas flow deficit is 10% of land price with a pe petual mortgage. Thus the tendency for farn land to become a growth stock in an unde achieving economy exacerbates the cash-flo problem.

For the beginning full-time owner-operato with limited potential to generate cash flov land is clearly "overpriced" with 9% inflatioı Operator-family labor-management returr are not expected to exceed 2% of land value in the 1980s, hence applying the entire amoui (if that were possible) to pay the intere would still leave a large cash-flow deficit wi 9% inflation. Principal payments only add t the cash-flow problem. Tenancy, off-far employment, and special assistance from pa ents and other concessional sources are var ous means operators use to cope with th problem. Unless new financial strategie sound monetary-fiscal policies, and oth measures are found to deal with the cash-flo squeeze, the trend is likely to accelerate t ward farmland ownership and operation b part-time farmers, corporate conglomerate and established, wealthy commercial farmer

Increased ownership of farms by these la ter groups conflicts with the traditional fami farm concept. Coupled with high overall cap tal requirements for an economic farming un the cash-flow squeeze has gone far to redu the farming industry to a landed class wherel the only family farmers who can become e tablished in farming are sons and daughters established farmers.

Fixed long-term interest rates inject u

cessary risk into the credit market, which uld cause severe financial hardship to rmer-debtors with the deflation that would llow a return to sound monetary-fiscal pol- y. Because the equity ratio is high in farming d because much of the current long-term bt was not incurred at high mortgage in- rest rates, it seems imprudent to continue o-Keynesian economics on the grounds that he only thing worse for farmers than flation is deflation." Indexed interest rates e one means to reduce risk to debtors and editors as monetary-fiscal policies change.

rving the Threatened Mid-Size imily Farm

any agricultural economists committed to rve the public interest have perceived farm- s to be a disadvantaged and oppressed class. here the interests of the farmer conflicted ith those of the public at large, it was easy to de with the farmer. The world is no longer at simple.

Cost-price difficulties will continue and ckets of low income farming will remain; t on the whole, cash-flow problems will rce ownership of farming sector assets into e hands of the financially strong. Per capita ealth will be considerably higher in the farm ctor than in the nonfarm sector.

Tweeten, Cilley, and Popoola show that the mposition of small farms, where low income oblems have been acute, will experience a arp turnaround. Once by far the largest cat- ory of small farms, those operated by full- ne, able-bodied persons will be compara- ely few in numbers by the mid-1980s. The tal number of small farms probably will gin to grow because of rising numbers of rt-time and/or aged operators. Part-time rmers are for the most part not a welfare oblem, and the aged are best helped by wel- e programs. Because these farmers produce little and are hard to reach, neither of the ter groups is a prime candidate for utilizing arger share of scarce agricultural research d extension resources.

Publicly supported agricultural research and tension needs to focus especially on the d-size family farms with sales of $20,000 to 00,000, that can be operated efficiently but e threatened by cash-flow and cost-price essures of neo-Keynesian economics (Tweeten 1979, pp. 70–75). These farms are less able to handle cash-flow problems than (*a*) small farms which receive large shares of in- come from off-farm sources and (*b*) large farms with access to diversified sources of earnings as well as equity and debt capital. Public research and extension will need to play a key role in improving efficiency (through improved technology, information, etc.) and financial management critical to for- mation and survival of moderate-size farms.

Impacts of a Shift in Economic Policy

The tide of political economy for the farming industry will drift with the tide of political economy for the nation. A turn to right-wing, post-Keynesian macroeconomics will mean an even greater market orientation for agricul- ture, with the government role restricted largely to correcting market imperfections, e.g., aligning private and social costs (ben- efits). The result could be continuation of conservation, information, and stability pro- grams such as the farmer-held reserve. But farm prices and incomes might not be sup- ported directly, farm import curbs might be eliminated and farm cooperative antitrust preferences might be withdrawn. The fate of public research and extension is enigmatic: would emphasis on supply-side economics bring greater outlays for public agricultural re- search and extension to substitute for higher- cost conventional sources of output? Or would a right-wing political economy be dominated by an overriding concern for cut- ting public spending? Outlays for public ag- ricultural research and extension could go up or down depending on the balance of these "substitution" and "income" effects.

The fate of tax policies is also enigmatic. Right-wing policies in general will result in lower income and estate taxes, which could favor growth in large, established farms. The resulting concentration of production in a few large farms may not be viewed with alarm if consistent with efficiency—such farms will be too numerous to form cartels and they will not be provided with enabling legislation in the form of market orders to facilitate collusion.

Pursuit of the left-wing model could bring all agricultural workers into a trade union. Ex- tension of marketing orders and the National Labor Relations Act to the entire farm sector

could set the stage for commodity-wide, perhaps nation-wide, collective bargaining over commodity prices and output. Farm cartels would not be allowed to set prices at will. The farming industry could become a giant public utility with wage and price changes worked out in negotiations with government and consumer. A milder scenario merely would continue current commodity programs but with more generous price and income supports. The left wing would place much more emphasis than the right wing on preserving a large number of farms through a structure policy including special tax advantages for small and entry level farms coupled with tax penalties against large agribusiness corporations.

Implications for Economic Theory

Scarcity is divisive and an underachieving economy exacerbates scarcity. An underachieving economy needs economics more and appreciates it less than does an achieving economy.

Kuhn lists two ingredients for a scientific revolution: a crisis in the old paradigm and availability of a superior replacement. Rates of unemployment and inflation near double-digit levels signal a crisis in the old paradigm. No satisfactory paradigm awaits to replace the existing economic theory. The most successful left-wing economies do not use price controls but exercise restrained monetary-fiscal policy in conjunction with a sociopolitical strategy of concentrated but accountable labor and industry power. The conceptual framework is not new but avoids excesses of neo-Keynesian macroeconomics. On the other hand, the right-wing model calls for a return to traditional neoclassical marginal economics, the classical quantity theory of money, and Jeffersonian democracy. The neoclassical competitive model has experienced a renaissance but not necessarily for its predictive value.

Rebirth of Neoclassical Theory of Pure Competition for Prescriptive Purposes

Right-wing post-Keynesian economics is especially difficult to relate to the public because it emphasizes deferred gratification and efficient sources of additional output rather than stimulation of demand with transfer pa ments for consumption. It is indeed "people" program, but benefits to people a less direct and often deferred as compared left-wing policies. Stress on efficiency oft concentrates wealth; the needs of the po remain, and the equity-efficiency quandry intensified as the pace of economic grow quickens. If the re-emerging neoclassical co petitive paradigm appears to be an anac ronism unable to deal with economic equit it is because our economics has been t small. Excessive emphasis has been placed prediction and Pareto-optimum efficienc The competitive model has much to say abo welfare maximization that economists ha been too timid to voice.

Since Friedman's *Essays on Positive Ec nomics*, it has been fashionable to regard theory as useful to the extent that it predic reality. Assumptions are of secondary impo tance. Students frequently protest neoclass cal competitive theory on that basis, sayi the model neither resembles nor predicts t real world. With modifications (to include t cost of time, risk, and information) the ne classical competitive model does predict re sonably well, but the competitive model is n critical for prediction—it is easily suppl mented and amended to include behavior and other elements of reality. (Whereas so reject the competitive model because it do not resemble the real world, others make t opposite mistake of equating a free mark with perfect competition.)

The most underutilized value of competiti theory is for prescription, as opposed to pr diction. Here the perspective is the reverse Friedman's: for prescription, usefulness of t competitive model lies in the fact that it do not resemble or predict the real but is a no for an allocation to improve well-being people. A device to detect automobile engi malfunction would be of no value if all engin functioned as predicted by their design specifications. Similarly, the competiti model is useful to diagnose inefficiency (le utility than possible from means availabl precisely because the real world does not r semble the competitive allocation. It is esse tial here to distinguish between pure (or pe fect) competition as a set of assumptions an pure competition as an allocation of resourc and commodities. In measuring social co and performance, the allocation of pure co

tition rather than the adherence to assump- ıns (e.g., many buyers and sellers) is impor- ıt. The competitive model is a tautology ıose marginal conditions and allocations ıst hold in a barter, socialist, or market onomy which prizes above all the well-being its people!

In short, Friedman's position that the test of theory is its ability to predict the real ›rld—assumptions are of secondary impor- ıce—is turned upside down. In prescriptive ; of theory, market concentration, degree of owledge, mobility of resources, and other ;umptions are hypotheses useful to judge portunities to improve allocations. Even t-wing cynics, who see nothing resembling re competition in the real world and who ll for enlarged collectives to exercise bar- ining power in all sectors, measure the in- iciency of economic systems by the rdstick of pure competition. But the com- titive model is not carried far enough. To ow that imperfect competition in the food- ırketing sector results in excess costs of $x lion is incomplete without examining costs reducing such inefficiency with alternatives ch as atomistic competition, cooperatives, government performing the food-marketing ıction.

ward Resolving the Equity-Efficiency 'andry

most serious shortcoming of the competi- e norm is that it is only a Pareto optimum, a sition from which one cannot be made bet- off without making someone else worse . A Pareto optimum can exist between two lividuals while one is starving and another is ed with goods and services. It is fashion- e for economists to recommend improve- nts in efficiency that make the sated indi- lual even better off, arguing that the issue of ııty should be left to radical social scientists l revolutionaries. That is precisely what has ppened too often, with tragic consequences. dical social scientists and revolutionaries have as if efficiency does not matter, ignore ; impact of redistribution on efficiency, and ıdvertantly invite trauma exceeding pre- /olution miseries. On the other hand, sitivistic economists often become hostages the status quo, behave as if distribution es not matter, and ignore concentrations of :alth that are setting the world aflame with social unrest. To ignore the equity dimension of economics is to ignore much of economics that is important in today's world. The neo-classical competitive economic paradigm has been labeled a tool of the "haves" to oppress the "have nots," legitimatizing inequality and encouraging increasing concentration of wealth. It need not be.

Neoclassical economics is robust enough to handle the conceptual and empirical modifications needed to specify an optimal distribution of resources that recognizes the utility-maximizing trade-off between equity and efficiency. What is required are measures of the marginal utilities of income and resources for groups of people. In a pilot study, Harper and I showed that intergroup (though not necessarily interpersonal) utility can be measured for policy purposes employing attitudinal scales and test instruments widely used and accepted by other sciences such as psychology and sociology. Positivistic economists have for the most part rejected such estimation to depict equity-efficiency trade-offs as subjective and value-loaded. Yet, the value judgments of the "positive" economists (that the marginal utility of income is constant and equal for all, and hence the distribution of income is of no concern) seem even more imprecise, subjective, and value-loaded.

Some express concern that economic prescriptions showing allocations of resources that would maximize utilities would be a threat to politicians, replacing their role of interpreting social welfare functions. That is unfair. The appropriate and positivistic procedure is to lay before politicians alternatives derived as objectively as possible: one (say) which increases income, another which decreases unemployment, and a third which increases utility. The politician is then free to choose among alternatives based on the trade-offs between serving his narrow constituency (perhaps of special interests) versus the public at large. The need to study equity-efficiency trade-offs is not restricted to left- or right-wing schools of economics; rather, such study can bridge some of the gaps between schools emerging from different perceptions of importance of equity relative to efficiency.

Summary and Conclusions

Neo-Keynesian macroeconomic theory and practice have helped to create an underachiev-

ing economy of crisis proportions. One road to the left from the current impasse calls for diminishing the labor-management conflict and for enhancing the concentration of power in labor and industry, while holding collectives accountable for acting in the public interest. One road to the right calls for reliance on competitive forces of the market to produce outcomes in the public interest. The United States is currently in an unstable situation between these extremes, with collectives too small to be held accountable for the nation's ills but large enough to aggrandize themselves at the expense of society. A move to the right or left that promises to restore economic vigor will come eventually, but an underachieving economy will continue to be manifest in the 1980s in the form of high unemployment and inflation rates, slow growth, and/or a weak dollar in international markets.

The underachieving economy and a turn to the right or left has strong implications for the farm sector. The backbone of the farming industry and the principal clientele of the land grant university, the moderate-size family farm is particularly threatened by the cash-flow and cost-price impacts of an underachieving economy. On the more optimistic side, the underachieving economy could change farming into a growth industry and increase the elasticity of demand to reduce the need for price supports and stabilization policies.

Farmers are reaping the bitter harvest of neo-Keynesian macroeconomic policy they did not consciously sow. They might well contemplate how to have a part in sowing the seed for the next harvest. Agriculturalists need to be as diligent in helping farmers choose a variety of macroeconomics as in helping them choose a variety of wheat. Farm organizations and spokesmen are powerful political forces, but for the most part they have not used their influence for constructive, consistent macroeconomic policy. The excesses of neo-Keynesian economics are not ultimately the fault of politicians but of citizens uninformed of the institutional requirements for operating a responsible economic system in a world where people and collectives pursue self-interests.

The economic structure of the farming industry in the long run will depend more on federal taxation, spending, money supply, and trade policies in the Federal Reserve System, the Internal Revenue Service, and Department of State than on commodity programs i the U.S. Department of Agriculture. Th "farm bloc," though less visible than befor still wields much influence in Washington. Be cause the future of the farming industry is s much influenced by sound monetary-fiscal po icy, it is well for farmers to turn some of the attention from traditional commodity pro grams to money supply, wage-earnings sup plements, measures to reduce labor-manage ment conflicts, and other macroeconomic is sues and policies so important to the economi well-being of the farming industry.

References

Committee for Economic Development. *Stimulatin Technological Progress*. Washington, D.C., Ja 1980.

Council of Economic Advisors. "Economic Report of th President." Washington, D.C., Jan. 1980.

Dernburg, Thomas, and Duncan McDougall. *Macroec nomics*. New York: McGraw-Hill Book Co., 198

Friedman, Milton. *Essays on Positive Economic* Chicago: University of Chicago Press, 1953.

Gardner, Bruce. "The Effect of Recession on the Rura Farm Economy." *S. J. Agr. Econ.* 8(1976):13–22.

Harper, Wilmer, and Luther Tweeten. "Socio-Psych logical Measures of Rural Quality of Life: A Pro for Measuring the Marginal Utility of Income *Amer. J. Agr. Econ.* 59(1977):1000–05.

Keynes, John Maynard. *The General Theory of Em ployment, Interest and Money*. London: MacMill and Co., 1947.

Kuhn, Thomas. *The Structure of Scientific Revolution* Chicago: University of Chicago Press, 1970.

Lucas, Robert, Jr., and Thomas Sargent. "After Keyn sian Macroeconomics." *Federal Reserve Bank Minneapolis Quarterly Review*, pp. 1–16. Mi neapolis, Minn., spring 1979.

Melichar, Emanuel. "Capital Gains versus Current I come in the Farming Sector." *Amer. J. Agr. Eco* 61(1979):1085–92.

Morley, Samuel. *The Economics of Inflation*. Hinsdal Ill.: Dryden Press, 1971.

Ruttan, Vernon. "Inflation and Productivity." *Amer. Agr. Econ.* 61(1979):896–902.

Tweeten, Luther. "An Economic Investigation in Inflation Passthrough to the Farm Sector." Mime graphed. Dep. Agr. Econ., Oklahoma State Unive sity, 1980a.

———. "Farm Commodity Prices and Income." *Co sensus and Conflict in U.S. Agriculture*, ed. Bru Gardner and James Richardson. College Statio Texas A&M University Press, 1979.

———. "Farmland Pricing in an Inflationary Economy." Mimeographed. Dep. Agr. Econ., Oklahoma State University, 1980b.

———. "Inflation Impacts and Implications for Research in Farm and Financial Management." Mimeographed. Dep. Agr. Econ., Oklahoma State University, April 1980c.

Tweeten, Luther, and Steve Griffin. "General Inflation and the Farming Economy." Oklahoma Agr. Exp. Sta. Res. Rep. P-732, 1976.

Tweeten, Luther G., Bradley Cilley, and Isaac Popoola. "Typology and Policy for Small Farms." Mimeographed. Dep. Agr. Econ., Oklahoma State University, 1980.

The Rise of Economic Power: Some Consequences and Policy Implications

A. C. Hoffman

The rise of economic power and its replacement of the Invisible Hand of Adam Smith as the regulator of economic activity is surely one of the most important developments of the century. Both within and without the profession there is growing concern about this. Despite this concern, it does not seem to me that there is as yet a general understanding of the direct relationship between economic power and the current condition of the economy. Nor has there been an in-depth investigation of the subject since the Temporary National Economic Committee (TNEC) of the 1930s.

In his presidential address to the American Economic Association in 1972, Galbraith took note of this deficiency. He suggested the need for a body of doctrine more appropriate for understanding and dealing with economic power than what has come down to us from Adam Smith. Clearly, neoclassical economics does not fill the bill.

When economists do address themselves to economic power (or monopoly—I shall use the terms interchangeably), their studies are usually limited to a particular product in a single relevant market; and they analyze its consequences in terms of prices, profits and output in the industry directly involved. There is nothing wrong with this and it is a needful thing to do, but economic power involves far more.

Inflation, unemployment, idle resources, an adverse balance of payments, an almost intolerable welfare burden—all are related in greater or less degree, and directly, to economic power. It would of course be a mistake to attribute all our woes to any single factor, even one as important as power; but the greater error is largely to ignore it and go chasing after lesser ones.

The Power Entities

Before going any further, perhaps we shoulc identify who some of the power entities are Big business and big labor are of course the two which come first to mind, but there are others, great and small.

Skeptics have long suspected that competition among small competitors in small markets may not be quite as perfect as we have imagined. Recently some enterprising fellow constructed a home-made index of the prices of goods and services charged by enterprisers in these small markets—I think he called it the "Knick-Knack" index—and, sure enough, it has been going up faster than the BLS index. I will not labor the point here, but neither should it be forgotten that economic power comes in small packages as well as large ones.

Among the big power entities is of course the government itself, which frequently uses its power to raise prices, restrict output, and restrain competition, just as big business and big labor are accused of doing. Those who do not understand the intricacies of agricultural economics sometimes point to the government's farm programs as examples of this. But there are others in these times who seek the exercise of governmental power in their behalf, and not always to the public good. The list of them is almost as long as the list of registered lobbyists in Washington.

It will be sufficient to our task here—I am afraid more than sufficient—to limit our discussion of economic power to big business and big labor. I bring no malice to the task. Quite the contrary, for many years I worked for big business. I believe it to be the cornerstone of the most productive economic system yet devised. And, as for rectitude and righteousness I think corporate bureaucrats will average about the same as government bureaucrats, or even college professors. As for organized labor, I think it represents one of the mos

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Fellows address.

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onstructive forces we have for a more umane America, not only for labor, but for nderprivileged people generally.

The trouble comes when big business and ig labor take actions in their own behalf—ctions which are entirely legal and within the oundaries of accepted business practice but which may not be in the public interest. Adam mith solved this conflict-of-interest problem y assuming a competitive model in which no ne had any power. Despite Milton Friedman nd the Chicago School, I am afraid we can no onger thus assume it away.

'he Roots of Economic Power

Economic power has its roots in economic tructure, so we will begin here. For generaons, conventional wisdom about economic tructure has tolerated and even encouraged fundamental error, namely, that competition ; the normal state of a modern industrial conomy. It is not; big business and oligopoly re and for reasons it is no longer necessary to o into before this profession. In most sectors f American industry, small and mediumized firms are long since gone, and only a andful of big firms remain.

Nor is there any stability even in this situaion. Both by merger and internal growth, the emaining firms go right on trying to increase 1 size, in share of market, in doing everything n a bigger scale than the year before. They re spurred on in this by institutional investors who want to see growth in those companies whose stocks they hold, and by those gadflies f corporate performance, the security anaysts, who think largely in these terms.

Now there is nothing wrong in this, per se. ncreases in size and market share (other than y merger) usually come as a reward for sucessful performance in the market place, and nore frequently than not are associated with echnological progress and efficiency. The rouble is that the corporate technostructure, 1 doing its job successfully, tends to drive its veaker competitors to the wall. Chrysler is he latest example; but in greater or less deree, it is going on throughout American inustry, and no end is in sight.

I am among those who believe we may be earer than we think to plain, simple, one- or wo-firm monopoly in quite a few vital sectors f industry.

Of Price and Output under Oligopoly

I shall discuss the consequences of economic power mainly in terms of what, in older days, we used to call economic theory. Events did not always turn out the way the theory said they should, but I guess that is the way with economics.

It is something of an over-simplification, but the essence of price-making theory can be stated about as follows: In the competitive model, of which agriculture is the best example, prices tend to rise and fall with changes in demand, with supply tending at least in the short run to remain fairly constant. At the other extreme is monopoly, where the monopolist has the power to raise or lower his price and output to maximize his profit. In between is oligopoly, a sort of fuzzy area where price is indeterminate. But the general view was that even in the more concentrated areas, competition among a few firms was "workable" in the sense that it tended to produce a price/output closer to the competitive model than that of monopoly.

So what is happening in most sectors of American industry today? The *sine qua non* of monopoly power is the ability to raise prices and reduce output in the face of falling demand, and that is precisely what is happening in the industrial heartland of America today.

The theory of price making under oligopoly is crucial to understanding the performance of American industry, so let us take a walk back into history and see how it developed.

Among the first to perceive the revolutionary changes being wrought by the rise of big business were A. A. Berle and Gardiner Means, whose monumental work, *The Modern Corporation and Private Property*, appeared about fifty years ago. They clearly saw that price making in a large corporation was not only administratively determined but inherently restrictive in the sense that supply would be controlled to achieve the desired price. They gave us a name for it, "Administered Prices." Curiously enough, the book did not receive the attention it deserved from the 'mainstream' economists of the day, but it had a great impact outside the profession.

At about the same time another book appeared, Chamberlin's *Theory of Monopolistic Competition*. Like Berle and Means, Chamberlin clearly saw that the competitive model was no longer valid for many parts of the economy. However, his theory was largely

cast within the paradigms of neoclassical economics, and perhaps for this reason received greater professional attention.

In essence, Chamberlin's concept was that where small numbers of firms are involved (oligopoly), the outcome as to price and output is indeterminate as between that of competition and that of monopoly, depending on how each competitor anticipates and reacts to the moves of the others. It was a kind of game-theory thing, which led naturally to the conclusion that the greater number of competing firms, the harder it would be for each to anticipate the other's moves, and hence the nearer the outcome would approach that of the competitive model. This in turn led to the concept of "workable competition," which consoled a whole generation of economists and still comforts many.

We now know that Chamberlin was basically wrong, and that an oligopolistic industry will follow much the same policy as to price and output whether it is comprised of two firms or ten—and usually without either overt or covert collusion because none is needed. I do not want to overstate the case here. Common sense tells us that from a competitive standpoint, ten firms are better than two, but observation tells us, not by much.

Big Business and Big Labor: The Symbiotic Relationship

Of great concern and growing annoyance to the public are those power confrontations which take place between big business and big labor when it is time to renew a labor contract. Galbraith has called this a "mating dance," with, it might be added, the government standing by wringing its hands and urging the two parties to consummate so a strike can be avoided. The unions, having the power to withhold labor on an industry-wide basis, are usually in position to drive a pretty hard bargain; and the companies, having the power to pass along any wage increase, plus maybe a little something for themselves, are not inclined to offer great resistance. Anyway, since all the firms involved will end up paying the same wage rate for labor, the actual level of wages is not of overwhelming consequence to them. Now this is the basis of cost-push inflation—we call it the wage price spiral.

Nor is this the only consequence of the symbiotic relationship between big business and big labor. It is difficult to measure, but n less true, that it also contributes, and directly to unemployment and the welfare burden Ancient theory had it that productive re sources idled by the exercise of monopol power would find employment elsewhere—th old "Allocation of Resources" doctrine—bu the unemployment figures and the welfar rolls these days do not give much validity t this anymore.

I am well aware that many economists con tend that organized labor does not create un employment, and argue to the contrary tha high wages increase purchasing power an thus reduce it. As to this controversy, I can d no better than refer to the presidential addres of Robert Solow to the American Economi Association last December on the causes c unemployment. Solow quotes approvingl from that old master of neoclassical econom ics, Professor Pigou, as follows: "If there i 'thorough-going competition' among work ers, then the only possible equilibrium posi tion is at full employment." He goes on t quote Pigou regarding trade unions: "O course, these agencies [the trade unions] wil have no wish to set wage rates so high that hal the people in the country will be thrown out o work. Nevertheless, there is reason to believ they do not have regard to the demand condi tions [for labor] in such degree as would b necessary to secure, as thorough-going com petition would do, the establishment of ful employment" (p. 4). Professor Pigou's pros is appropriately solemn and obtuse, but hi meaning is clear.

Consider the following sequence of event in the steel industry. The steel industry i comprised of ten or a dozen firms (it is hard t keep track, there may have been a merger) an a union which does industry-wide bargaining Some months ago a new wage contract wa negotiated, which the union president de scribed as the most favorable the union ha ever received—this in an industry where wag rates were already among the highest in th economy.

At about the same time, the steel companie announced a price increase. As I recall, it wa their third within a year. Next came the inevi table follow-up that there would be a cutbac in steel production. The industry is operatin presently at about 50% of capacity.

Recently the companies and the union wer all down in Washington, trying to get the gov ernment to limit steel imports.

Several years ago Russia overtook the United States as the world's leading steel producer.

But some good may yet come out of this deplorable situation. Recently U.S. Steel permanently closed one of its plants in Youngstown, Ohio. Some of the former workers in the plant are trying to form a consortium to reopen the plant and operate it for their own account. They have asked the government for a loan, and have cited the Chrysler bail-out as a plausible reason why they ought to have one. The project probably will not get off the ground because this kind of thing is not yet accepted public policy in the United States, but it just might work out to everyone's benefit if it did.

Bilateral Monopoly: A Neglected Concept

A neglected but very important concept with respect to the consequences of economic power is bilateral monopoly. It relates to a situation in which power entities deal with each other vertically—at successive stages in the marketing system, as buyer and seller, as bargaining groups, or between big business and big labor in the setting of wages.

There are two diametrically opposite views among economists as to the consequences of bilateral monopoly. In his *American Capitalism*, published about thirty years ago, Galbraith treated it under his concept of countervailing power. His conclusion was that the power entities tended to offset each other, and went so far as to say that this was a sort of self-regulating substitute for competition itself, and clearly in the public interest. Apparently he did not think this was one of his more inspired insights, and in his later and more definitive work he largely abandoned it.

Joe Bain, whose *Industrial Organization* is usually regarded as the Bible for the structure-conduct and performance school, seems largely to have missed the importance of bilateral monopoly. He does not even relate it to the wage-price spiral, and considering that his book was published in the 1950s, this is amazing. He devotes only a few pages to the concept, concludes that the results appear to be largely indeterminate, but insofar as there is a central tendency, "the overall or average effect of bilateral oligopoly negotiations is in fact or should be generally to produce a competitive price of the sort which might rule if both buyers and sellers were numerous and individually small" (p. 337).

So far as I am aware, the first economist of note to take the opposite view was Cournot. He reasoned that under bilateral monopoly, each monopolist takes as the basis of his own operations the monopolistically determined price or output of the other with whom he is dealing. Obviously, in such a situation, bilateral monopoly is restrictive in its effect, and synergistically so. An interesting derivation from this is the paradox that two monopolists, dealing vertically with each other at successive stages in the marketing system, may be worse for the public than a single monopolist combining both their functions!

I first became interested in bilateral monopoly more than forty years ago when writing a monograph for the TNEC, *Large-scale Organization in the Food Industries*. I thought then, and still believe, that Cournot's restrictive concept of it was the correct one. The late William Nicholls, working independently in the same field at about the same time, came to a similar conclusion (*Imperfect Competition within the Agricultural Industries*). Neither of us then saw its importance and broad application.

If examples of bilateral monopoly are needed, they abound. We have just seen how it is one of the root causes of the wage-price spiral and cost-push inflation. Many observers, in fact most of them, point out a similar relationship between the Organization of Petroleum Exporting Countries (OPEC) and the big oil companies.

Application on a lesser scale can be made to the bargaining process by farmer cooperatives. This becomes increasingly important these days as antitrust officials are bringing the cooperative movement under closer scrutiny. Many agricultural economists are arguing that equality of bargaining power in the market place results in benefit to the farmer in dealing with buyers who may have monopoly power, as of course it does. But frequently they go on to argue that such bargaining tends to produce a price outcome near the competitive model and thereby also benefits the public (Bain's concept). In his work cited above, Nicholls demonstrated, and I thought rather convincingly, that when organized milk producers bargained successfully with milk distributors, it was the milk consumer who largely paid for the bargaining gains of both. The qualification must be added here that farmer cooperatives rarely

achieve a control of supply adequate to give them much monopoly power.

Many years ago, using Cournot's concept, I put forth the view that vertical integration was frequently in the public interest, as when a grocery chain integrates backward to cut through a monopolistic situation, or a food manufacturer integrates forward into distribution or backward into the self-manufacture of some of its supplies for the same reason. I never got very far with it. But recently, in looking through some of the economic journals to see what economists are up to these days, I found several articles by young economists who have dusted off Cournot and are having another go at it.

One of the most interesting applications of bilateral monopoly is "indexing" to compensate for inflation. This is being done increasingly these days—in wage agreements, business contracts, social security payments, and recently some of the OPEC countries have suggested hooking the price of their oil into our inflation rate, which could turn into a fine kettle of fish! The result of such "indexing" is clearly to add to inflation, and there is no end to it.

Before moving on to some of the implications of economic power for public policy, a final summation as to its consequences: In times of stagflation, the consequences of such power (whether exercised vertically or horizontally, by private entities or by government in behalf of private groups) are clearly restrictive as each such entity tries to improve (or hold) its position against other groups trying to do the same thing. In economic fair weather, the same inherent tendency is present, but so many good things are happening that we do not seem to worry much about it—at least not thus far.

Some Policy Implications

I am among those who believe that capitalism itself is in greater danger today than at any time since the early 1930s. In some respects the situation is even worse, since there seems to be no sense of direction, other than the old and discredited nostrums, as to what to do about it. In what follows, I do not ask you to share my point of view, only my concern.

Antitrust versus Control

There are basically two schools of thought with respect to dealing with economic power. The first would do it under the antitrust concept, by trying to preserve both the structure and the practice of competition. The other school has no great faith in antitrust, and would move in the direction of government control. Perhaps I should also mention the newly emerging third school—those who think we already have too much government regulation and would, in that happy phrase, "unleash competition." I cannot bring myself seriously to discuss this third school.

The major criticism of the antitrust laws is that they have not prevented what has happened. This is of course true, but I do not on that account think they should be abandoned. Antitrust is for the time being about the only weapon the government has, and it could be amended to make it a good deal more effective than it is.

One thing currently being proposed is to proscribe, unconditionally, all mergers between large firms. I am not at all sure I agree with this. For one thing, it would not restrain internal growth toward increasing concentration of control. And in some cases a merger of large firms might be in the nature of a "rescue operation" and serve to preserve or even increase competition. But certainly the government should have, in clear and unmistakable terms and without all the hassling around in the courts, the right to prevent a merger when it tends to lessen competition.

Another proposal for amending the antitrust laws was advanced a decade or so ago by the late Senator Hart. It would have provided, in certain key industries, for some restructuring, by dissolution proceedings, to increase the number of competing firms. I was in favor of this legislation and testified before several congressional committees in support of it. But for reasons discussed earlier in this paper, I did not have as much faith as some of its other supporters that it would greatly change price-output performance under oligopoly.

Toward Control

I am among those who believe we must move in the direction of government control of private economic power. There are those who hope that somehow this can be avoided, that the basic conflict-of-interest problem can be solved by adjudication and voluntary means rather than by confrontation. I cannot find much in economic history to support this.

There is growing support these days for greater public representation on the governance bodies of big business and big labor. An

example is the recent placing of a labor union representative on Chrysler's board of directors. Many nowadays are proposing that one or more public representatives be placed on corporate boards of directors and labor union organizations, and there is much to be said for this. But I do not believe that basic conflict-of-interest decisions as to wages, prices and output can be resolved by debating them in corporate board rooms or labor union councils.

As we move in the direction of control, where do we start?

With rolling inflation largely of the cost-push type and feeding on itself, I think we need a wage-price freeze, and quickly. According to the polls, a majority of the American people, if not of economists, are in favor of this.

It is a funny thing about economists and price control. For as long as I can remember, the leading pundits of the profession (not quite all of them) have proclaimed and put it in their textbooks that price control will not work. Then they defend this position by offering as proof that prices tend to go up after price controls have been removed! Now no one argues that price control, in and of itself, is a permanent cure-all for inflation. But in an emergency situation it is a useful tool, and about the only one we have which can be applied quickly and directly while more permanent measures are being put in place.

Even though we finally manage to slow down the current rate of inflation, if we do, by bleeding ourselves half to death in recession, the problem of economic power will remain. I believe it may therefore be necessary, as a long-run measure, to have some kind of wage-price guidelines in those sectors of the economy where economic power rather than competition clearly rules the market place.

Even this may not be enough. It may be necessary to give what amounts to public utility status to certain key industries where virtually no competition remains. I am aware that it is currently the fashion to condemn public utility regulation as inept, ineffective and sometimes venal, and in some cases this may be true. But what is the alternative? Unless we are prepared to live permanently with unrestrained economic power, nothing may be left in some situations but nationalization.

Capitalism and Socialism

Unlike most West European countries which have had an important socialist movement for nearly two centuries, most Americans shun anything which smacks of socialism. I wonder if this is any longer a reasonable, or even a possible, thing to do.

The central problem of capitalism is unemployment, and except in times of war, this has been true throughout the twentieth century. Along with basic unemployment is the fact that many sectors of the economy are starving for labor and capital investment because private enterprises cannot make an adequate profit there: rebuilding of inner cities, low-cost housing, public transportation, environmental control—the list of things to be done is endless.

For years we have been attacking these great problems with palliatives and half-measures: government unemployment projects (mostly of a leaf-raking type and on a temporary basis), training for jobs which do not exist, tax incentives, or, as the politicians keep telling us these days, tax cutting to "get the economy moving again."

Surely the time has come to cut through all this, and for the government itself to move directly on the unemployment problem, on a permanent basis, with useful public service employment in areas where it is most needed, and in an entrepreneurial capacity. This is socialism. The alternative is more welfare.

Some jobs these days are too financially risky and just too big even for the biggest of the big corporations. One of these is the production of synthetic fuels. The Congress has recently passed the synthetic fuels bill, which provides large sums of money for a kind of joint enterprise between the government and private industry to produce synthetic fuels. In the legislative debate which preceded passage of this bill, some legislators criticized it on the grounds it was socialism, others praised it as the most important piece of legislation in several decades. However this may be, I think we shall be seeing more legislation of this type in the years ahead, and should.

As many suspect but do not openly say, the Chrysler bailout opens up a Pandora's Box for all sorts of things, including some socialism. The American taxpayer is long-suffering, but sooner or later he may tire of paying out large sums for "loans" to bankrupt corporations, and demand of his government that it either let them go broke or take out a mortgage and foreclose if they can not repay the loan. About the only way the government could do this would be to take an equity position in the firm, which is of course socialism. But this might not be all

that bad. Several government-owned European companies manage to make automobiles, and even sell them in the American market.

If and as we move in the direction of more socialism in the economy, and I think we will have no alternative, it ought to be understood that the purpose is not to supplant the private enterprise system where it is doing a good job, as will be the case in most places most of the time, but to supplement it in those areas where it is not.

It may well be that if capitalism is to survive in anything like its present form, it may have to co-exist with a little socialism, and this may indeed be the best of all possible worlds.

I can think of no more appropriate way to close these remarks than by reference to a recent address by Felix Rohatyn to The Conference Board. Rohatyn is a senior partner in a prestigious Wall Street firm, was Chairman of the Municipal Assistance Committee which recently arranged the financial rescue of New York City, and is a highly respected member of the business community. He believes, his words, that the economy is out of control and heading toward bankruptcy, and that capitalism itself is in jeopardy unless something of consequence is done.

Among other far-reaching measures, Rohatyn proposed a modern Temporary National Economic Committee, patterned after the old TNEC of the 1930s, but with a broader charter. It would be charged with developing an integrated economic strategy for the balance of the twentieth century.

Rohatyn would give a prominent role in the new TNEC to the economics profession, just as it had in the old one. I cannot think of anything better for the profession, especially at this time. Many economists are in some disarray these days, following the failure of "The New Economics" for which so many had such high hopes. But this failure will not have been an unmitigated disaster, if it helps the profession turn away from the past and move forward into new ways of thinking about the great problems which confront us. Certainly the people have no better place to turn for help.

Good luck to all economists everywhere.

References

Bain, Joe S. *Industrial Organization*. New York: John Wiley & Sons, 1959.

Berle, A. A., and Gardiner C. Means. *The Modern Corporation and Private Property*. New York: Macmillan Co., 1952.

Chamberlin, Edward H. *The Theory of Monopolistic Competition*. Cambridge, Mass.: Harvard University Press, 1933.

Cournot, A. *Researches into the Mathematical Principles of the Theory of Wealth* (English translation by Nathaniel T. Bacon). New York and London, 1897.

Galbraith, John Kenneth. "Power and the Useful Economist." *Amer. Econ. Rev.* 63(1973):1–11.

———. *American Capitalism: The Concept of Countervailing Power*. Boston: Houghton Mifflin Co., 1952.

Hoffman, A. C. *Large Scale Organization in the Food Industries*. Washington, D.C.: Temporary National Economic Committee Mono. No. 35, 1940.

Nicholls, William H. *Imperfect Competition in the Agricultural Industries*. Ames: Iowa State College Press, 1941.

Rohatyn, Felix G. Syndicated news story by Tom Wicker, *St. Louis Post-Dispatch*, 13 May 1980.

Solow, Robert M. "On Theories of Unemployment." *Amer. Econ. Rev.* 70(1980):1–11. Internal quotation is from A. C. Pigou, *Lapses from Full Employment*. London, 1945, p. 26.

Effects of the International Donor Community on Farm People

Theodore W. Schultz

According to biblical law, being rich makes it hard to get into heaven. The corresponding law in economics is: Being rich makes it hard to comprehend the economic behavior of people in low income countries. The struggle of the Scandinavian immigrants to the United States is poignantly recorded in E. O. Rolvaag's *Giants in the Earth.* By today's standards, they were indeed poor. Among them there were notable individuals who understood better than most of us the difficulties faced by farmers who are poor. But in the complex economy of the United States today where farm people, in spite of their abundant productivity, derive over half of their income from off-farm sources, the simple truth is that it is exceedingly difficult to comprehend the preferences and scarcity constraints that determine the choices farm people in low income countries make.

Most of the people throughout the world are poor; and most of the world's poor are farm people who earn their living from agriculture. If we had a comprehensive understanding of the economics of agriculture, we would know much of the economics of being poor. I have argued elsewhere that economists find it hard to understand this part of economics (Schultz 1980b).

I have also argued that our studies of the economic dynamics of low income countries have suffered from several intellectual mistakes. The major mistake has been the presumption that standard economic theory is inadequate and that a different theory is needed. New economic models developed for this purpose were widely acclaimed until it became evident that they were at best intellectual curiosities. Most economists, however, who specialize in this branch of economics have come to realize that the received core of economic theory is fully as applicable to the scarcity problems that confront low income countries as to the corresponding problems of high income countries. Another mistake is to neglect what can be learned from the economic history of Western Europe during the centuries when most people on the continent were poor. Still another mistake is to give too little attention to the economic behavior of farm families, especially as they opt for improvements in education and health—the so-called contribution to the stock of human capital.

Although there remains much about the economics of being poor that we do not understand, we know more now about the economic dynamics of low income countries than we did a few decades ago. We have learned that poor people are no less concerned about improving their lot and that of their children than those of us who have incomparably greater advantages. In their small private domain, they are competent in obtaining the maximum benefit from their limited resources. In a number of low income countries, the record in improving population quality and in acquiring useful knowledge is positive. Where this is true the economic prospects can be seen as favorable, provided they are not dissipated by governmental policies that discriminate against agriculture.

I want now to examine how actions of the international donor community affect farm people in low income countries. Specifically I will offer a critique on the following classes of foreign aid activity: research, capital for agricultural development, dumping and tied aid, arrangements for experts, the equity-productivity tensions, role of the market, and the distortions of agricultural incentives.

Foreign Aid Puzzles

The United States has long been a donor of various forms of aid. The economics of aid is beset with puzzles. Why was the aid provided by the Marshall Plan so successful? Why has

Invited address.

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the large amount of aid extended to low income countries been much less successful? Why did the Point Four Latin American Aid program contribute so little to the productivity of agriculture in our hemisphere? There is also the puzzle of why our private foundations—except in the case of agricultural research—have had limited success in improving the economic environment and schooling of farm people in low income countries.

Attributes of Aid

The international donor community has become a large, complex organization. It should be noted that most of the members of this community have evolved a "live and let live" policy in support of their common interest; and that interest depends less on the support of the countries receiving aid than on that of the high income and oil-rich countries providing the funds. Quite a few of the many donor agencies with their varied programs maintain regional and country offices. They recruit and finance development and welfare experts, donate resources in kind (mainly food and agricultural commodities), provide emergency relief, finance agricultural research and extension, control large funds for agricultural development, and acquire stocks of food grains presumably to stabilize the supply available to low income countries. The international donor community supports the World Bank and various regional banks. Donor agencies also produce and distribute information tailored to support their objectives.

Yet foreign aid of these kinds is still an ambiguous concept in economics; the dialogue between economic theory and observable foreign aid is not one of the cogent parts of economics. Thus, my presentation is exploratory; there is no generally accepted economic rationale for foreign aid on which I can build in order to determine its economic effects with some precision. Studies of foreign aid based on political considerations are not as a rule useful for economic analysis.

Foreign aid nevertheless has substantial economic properties. Obviously, resources entering it are sufficiently large to have economic effects on both donors and receivers.

A personal account may be instructive. While I was with the Army of Occupation at the end of World War II, I had the good luck of anticipating the reasons for the success of the Marshall Plan. The war had destroyed a great deal of the physical capital of Western Europe, whereas the human capital had been much less impaired. Recovery depended primarily on rebuilding factories and houses and acquiring equipment and inventories. The Marshall Plan contributed a good deal of capital for these purposes. Western Europe and also Japan, given strong market demands and international trade, recovered rapidly. The economic importance of human capital and of domestic and international markets is clearly illustrated. But this lesson has been persistently overlooked in providing aid to low income countries. All too little foreign aid has been allocated to enhance the stock of human capital and to strengthen markets in these countries.

The agricultural failure of Point Four aid is also instructive. In the early 1950s the Ford Foundation made a generous grant to the National Planning Association to evaluate the technical assistance of Point Four throughout Latin America. I agreed to serve as the director of that enterprise. We discovered the reasons for the failure of the agricultural part of that program. It was that the design of Point Four was based on the assumption that research knowledge was adequate and only a delivery system was lacking. But the extension services developed cooperatively with host governments failed when little worthwhile technical information was found to be available for distribution.

Approaches to agriculture taken by the major foundations are a mixture of pluses and minuses: the early Ford Foundation agricultural program in India was a premature commitment to extension activity; by contrast, the agricultural research program by the Rockefeller Foundation in Mexico, cooperative with the government of that country, was a successful innovation. The Kellogg Foundation is committed by its charter to extension activities. The International Agricultural Research Centers are a major innovation in principle, on a par with that of the Rockefeller Foundation in Mexico. The Centers initially financed by the Ford and Rockefeller Foundations were joined later by the Canadian International Research Development Centre. The total annual budget of the twelve International Agricultural Research Centers has since come to exceed $100 million. Most of the funds now come from the World Bank, regional banks, USAID, Canadian aid, Western European donors, and Japan (Schultz 1979).

A Modest Economic Critique

Farm people in low income countries have virtually no direct contact with the international donor agencies, except for a little in agricultural research. For all practical purposes farm people have no influence on what these donor agencies do to affect their wellbeing. Foreign aid is predominantly a public activity, where governments deal with governments and where UN agencies—which are also public entities—deal only with the host governments. In the interactions between these respective public bodies, most of the reckoning of economic effects on farm people is swamped by political considerations. In view of the heterogeneity among low income countries—including their governments—and given the various classes of foreign aid, only a few useful generalizations can be offered.

Research

Achievements in agricultural research are substantial, despite the limitations of some of the donors. United Nations agencies have a poor record except in their recent financial support of the International Agricultural Research Centers. U.S. bilateral aid has a mixed record; most of it is marred by a lack of continuity in research support. Congress is largely to blame, having imposed on AID a structure that is inefficient in funding agricultural experiment stations and laboratories in low income countries. AID has neither a professional staff nor an appropriate mandate to finance long-term research. A low income country cannot depend on either UN agencies or U.S. bilateral aid for resources to develop its own agricultural research capacity.

Agricultural research in many countries is organized primarily to improve the biological possibilities of crops and livestock. Its genetic and breeding success is not in doubt. Too little attention is given, however, to the economic constraints that farmers in low income countries face. Some of the International Agricultural Research Centers are beginning to examine the economics of farmers' response in adopting new crop varieties. But as yet IARC economists have only a tenuous footing in the centers.

Distortions in incentives lead to unevenness among low income countries in farmers' opportunities to take advantage of agricultural research. No donor agency, no host government, and very few agricultural research organizations appear to be aware of the adverse effects of distortions on the modernization of agriculture.

Much more neglected is publicly funded research to improve the technology of farm household production. A growing and overdue concern is now expressed to improve the opportunities for women in low income countries. But it seems odd that virtually no attention is being given to farm household production, the domain of women. Simple things are called for. For instance, in rural Senegal women use heavy wooden clubs to free grain sorghum (a major food crop) from its husk. It is arduous work done under a tropical sun. In each of three villages I visited, the women asked me, "Why can't we have a simple hand mill to do this task?" My plea is for technical research and business enterprise that would make it possible to modernize household production.

The last item on my research list is food and nutrition research, still broadly neglected. I know of no international donor agency that has established, in cooperation with a host government, a viable and competent food and nutrition research center. Instead, donor agencies make pronouncements—largely self-serving—on the dire consequences of malnutrition in low income countries. It is not cynical to infer that the donor agencies know full well that pictures of malnourished children along with statements on the vast extent of malnutrition, which are far from creditable, serve their self-interest in appealing for more donor country support. Financial support for competent, unbiased, well-organized food and nutrition research is very much called for. An important part of it should deal with the economics of food and nutrition, the role that consumer preferences and income constraints play, and the implications for agricultural production. Then too, economists should be aware that the widely used calorie standard is a misleading concept of the relationships between malnutrition and poverty. C. H. Shah's presidential address to the Indian Society of Agricultural Economics on "Food and Nutrition: A Perspective on Poverty" is a useful contribution dealing with this issue.

Funds for Agricultural Capital

The donor agencies provide capital for various purposes: fertilizer, irrigation, rural roads,

farm equipment, others. The World Bank, regional banks, and various other UN agencies and also bilateral agencies administer the allocation of these funds, which are now sizable. Given time for these "investments" to be completed, they will undoubtedly increase to some extent the capacity of agriculture in some low income countries. But there is considerable misallocation in the use to which these forms of capital are put. It could not be otherwise in view of the prevailing distortions in agricultural product and input prices in many of the countries. The allocations are also marred by the funding of massive irrigation projects, which as a rule are a mistake. The Inter-American Development Bank this past year attained its goal of loans for rural development. But it did so by approving three large irrigation projects toward the end of the year that in all probability will have extremely low, if not negative, net yields. The uses to which these funds are put are also seriously marred by the prevailing equity doctrines of the international donor community.

Dumping and Tying

Aid in kind has the effect of dumping. It is a convenient way for a donor country to dispose of its own burdensome surplus. It has the effect of increasing the capacity of the government that receives such aid to continue discriminating against its own agriculture by procurement methods, marketing boards, or other means that maintain a cheap food policy, which in turn distorts agricultural incentives. As a case in point, Indian farmers felt the adverse effects of our delivering vast quantities of P.L. 480 agricultural commodities during the 1950s and 1960s. The rhetoric was "Food for Peace." Currently the large P.L. 480-type aid to Egypt has the effect of underwriting the bad internal agricultural policies of that government. This form of dumping also impairs the international markets for agricultural commodities.

The extent and effects of tied aid are difficult to observe. Tied aid occurs mainly in connection with funds and grants that are made available bilaterally. The donor government insists that a part of it be used to purchase materials, commodities, or services from its own country. Although an accounting of tied aid rarely surfaces in published records, there is evidence that over 70% of U.S. aid is tied. Privately, economists in low income countries reveal the consequences of particular tied aid. For example, Sweden recently offered India a generous training grant in forestry. After two years of negotiations, however, the Indian government was unable to eliminate the tied conditions that Sweden insisted upon. For that reason the grant was not accepted. Weaker countries do not do what India did.

Providing Donor Experts

Experts recruited from high income countries are expensive. Total costs per U.S. expert made available by U.S. aid agencies are about $100,000 a year. Often these experts are less qualified than the indigenous corps staff with whom they work. Much money is wasted in providing such experts. Agricultural personnel from land grant universities serving low income countries are increasingly subject to the same limitations.

Productivity-Equity Tensions

At present it is the policy of most members of the international donor community to reduce inequality in the distribution of personal income and wealth, even though it impairs the potential productivity of agriculture. The equity objectives are those that the high income donor governments find appropriate for their own country. The higher the personal income of the donor country, the less appropriate is this approach to the equity problems in low income countries. Sweden qualifies as the most serious offender in promoting its concept of equity in foreign aid. The effects of Sweden's aid in supporting undemocratic governments and in impairing agricultural productivity are lost sight of. These are the consequences I see in Tanzania. To a lesser degree, other donors are bent on similar equity objectives at the expense of the potential increases in agricultural productivity. United Nations aid agencies have the same bias, as does USAID. Congress, in effect, demands such equity objectives, despite the fact that the results of similar domestic policies have failed. (Congress has appropriated much money to improve the economic lot of small U.S. farmers, yet despite dedicated personnel administering them, the programs have failed.) Still, Congress expects low income countries to succeed in similar programs. It is noteworthy that the larger low income countries with via-

ble governments are resisting this policy. Small countries with weak governments are unable to resist and accordingly forego the enhancement of food supply that a modernized agriculture could bring forth.

Debasement of Markets

It is necessary to distinguish between activities in which governments have a comparative advantage and those where the market has a comparative advantage (Schultz 1980a). By this test most organized agricultural research is a function of government; agricultural research that is financed by government produces primarily public goods. In the United States, only 25% of all agricultural research is done by private firms for profit. In low income countries private firms do much less of such research. The U.S. Department of Agriculture has a marked advantage in producing and reporting agricultural statistics. The government also has a strong comparative advantage in the domain of specifying standards of measurement for products that are bought and sold. It is the primary authority in determining the property rights of buyers and sellers of products. Inspection of agricultural products with special emphasis on food is done primarily by government. The maintenance of a constant general level of prices is one of the functions of government. In high income countries, endeavors to reduce the inequality in the distribution of personal income are mainly a part of the role of government.

The comparative advantages of the market in agriculture and in other parts of the economy are neither acknowledged nor supported by most of the members of the international donor community. Donor agencies with few exceptions are strongly biased against markets. They thrive on the rhetoric of market failures. Most host governments also have a vested interest in this bias. Those International Agricultural Research Centers about which I have knowledge are among the exceptions. Private foundations tend to be ambivalent.

The comparative advantage of the price-making activity of markets, despite imposed handicaps rationalized by the doctrine of market failures, continues to be demonstrable. No government that has abolished markets has been successful in modernizing agriculture. The inefficiency in the allocation of agricultural resources in centrally controlled economies is not in doubt. Governments of low income countries that procure food grains from farmers at below market prices reduce the possibilities for their farmers to modernize agriculture. Nationalized pricing and distribution of fertilizer has been inefficient and wasteful. The governments of many low income countries, despite the urgent requirements for more agricultural production, underprice their agricultural products. In most of these countries, free trade and internal farm product and input prices at prevailing international prices would be a boon for the modernization of their agriculture.

But donor agencies are in general so strongly committed to the doctrine of market failures that they are incapable of perceiving the comparative advantage of markets. The economic effect of a good deal of foreign aid is to strengthen the capacity of the host governments to discriminate against agriculture.

It should also be noted that our domestic proliferation of political groups bent on promoting government regulations to keep farmers from poisoning the soil, from contaminating streams and the water supply, from depleting the cropland, from using a long list of man-made chemicals, and from destroying endangered species, provide ever more support for the doctrine of market failures. A market-oriented agriculture is viewed by these groups as an environmental and social hazard. Donor agencies, as should be expected, take full advantage of the political success of these groups that specialize in market failures. Government failures in controlling agriculture, including the failures of the donor agencies, are rarely on the agenda. It should not come as a surprise that the potential agricultural production in many low income countries is impaired by the resulting distortions in agricultural incentives.

I shall not elaborate further on distortions of agricultural incentives since I had referred to them repeatedly, as I have recently edited a major book devoted to this pervasive economic problem (Schultz 1978).

Two additional attributes of aid agencies call for brief comment. Small countries and countries regardless of size that have weak governments find it exceedingly difficult to cope with the vast number of donors. Bangladesh's weak government is confronted by over a hundred donor agencies. There is no way the government can ensure that the country's public interest is being served. Kenya, which has a viable government, faces a similar

problem. She recently requested the International Agricultural Development Service (a foundation) to advise her on how to cope with the proliferation of donor agencies.

Last is the distortion of information distributed by donor agencies. Much is false bad news intended to win more financial support for the agency. Simon has devoted a major paper to such false bad news. He cites the 1977 UN statement that "more than 100,000 West Africans perished of hunger" in the Sahel between 1968 and 1973 and he shows it is false. How valid is the bad news that "14 million acres a year are vanishing as deserts spread around the globe?" The truth is exactly the opposite as a country-by-country survey of the changes in arable land shows. A United Nations commission predicts "500 million starvation deaths in Asia between 1980 and 2025." The contrary evidence is strong. To the World Bank and USAID it is almost gospel that "higher population growth implies lower per capita economic growth." Here, too, there is much evidence to the contrary. The USAID publication, *Agenda*, is a fountain of bad news: earth, water, and air casualties; U.S. industries wanting to dump toxic wastes in the Third World; the threat of pesticides; time bomb in the city; the impairment of the environment in the Third World; and on and on. The "Global Report to the President's Council on Environmental Quality" is still another example of this class.

There are a few economists who have expressed concern about some of the adverse effects of foreign aid. Bauer (1972, 1980) has done yeoman work on the liminations of foreign aid. Lele (1979) has made a first rate contribution in the postscript to reissue of her book on Africa. Schuh (1978) clarified important aspects of the equity-productivity problem.

Concluding Remark

My exploratory endeavor suggests that neither the donor agencies nor the host governments with which they deal know or appear to want to know the preferences and the resource constraints that determine the choices that farm people in low income countries prefer. Farm people in most of these countries continue to have little or no political influence to eliminate the prevailing discrimination against agriculture. Distortions of agricultural incentives are endemic. International and domestic markets are deemed to be failures for which governmental substitutes must be developed. Most donor agencies do very little actually to improve the schooling and health of farm people. The achievements in agricultural research are an exception, mainly because of early innovations by private foundations and early research programs of a few land grant universities. Governmental programs designed strictly for emergency aid, however, deserve a high mark.

Farm people in low income countries deserve a much better deal than they are receiving from the international donor community. Would that economists were providing the analytical foundation for this to occur!

References

Bauer, P. T. *Dissent on Development*. Cambridge, Mass.: Harvard University Press, 1972.

———. "The Harm That Foreign Aid Does." *Wall Street Journal*, 9 June 1980.

Lele, Uma. *The Design of Rural Development: Lessons from Africa*, pp. 227–56. Baltimore, Md.: Johns Hopkins University Press, 1979.

Schuh, G. Edward. "Approaches to 'Basic Needs' and to 'Equity' that Distort Incentives to Agriculture." *Distortions of Agricultural Incentives*, ed. Theodore W. Schultz. Bloomington: Indiana University Press, 1978.

Schultz, Theodore W., ed. *Distortions of Agricultural Incentives*. Bloomington: Indiana University Press, 1978.

———. "The Economics of Research and Agricultural Productivity." International Agricultural Development Service Occas. Pap., New York, 1979.

———. *Markets, Agriculture and Inflation*. L. J. Norton Lecture, University of Illinois, Urbana, 11 June 1980a.

———. "The Economics of Being Poor." *J. Polit. Econ.* 88(1980b):57–79.

Shah, C. H. "Food Preferences and Nutrition: A Perspective on Poverty." Indian Society of Agricultural Economics, Bangalore, India, 18 Dec. 1979.

Simon, Julian L. "Resources, Population, Environment: An Over-supply of False Bad News." *Science*, 27 June 1980, pp. 1431–37.

U.S. Small Farm Policy Scenarios for the Eighties

Frederick S. Humphries

I consider it an honor to have been invited to address this annual meeting of your association. As president of a land-grant institution, I have a particular concern for your work.

Your successful work has affected the agricultural policies of the nation. I certainly want to add my congratulations to your successes, but I am moved to challenge you to focus your talents on public policy and social science research for small farmers. Their cause represents a most exciting proposition.

The traditional debate over "agricultural policy" has been expanded to include equity. The nation no longer is interested in just food and fiber production. Costs to consumers and rural developments have become major issues. I believe agricultural economists have major responsibilities and a vital role to play in solving the problems of small farmers.

Background

Agriculture is one of America's most crucial sectors. It is big business and has great potential in the international arena. According to the U.S. Department of Agriculture's (USDA) "Agricultural-Food Policy Review," the agriculture sector had nearly $30 billion in exports in 1978. Agriculture's role as a "balancer of the books," vis-à-vis international trade markets, allows the United States a greater deal of leverage in minimizing balance-of-payment deficits.

The land-grant universities, with their agricultural research, extension, and teaching programs, are a part of the American agrarian tradition. The primary role of these institutions has been to change and modernize agriculture. These institutions provided the technology for the agricultural revolution. Improved technology released labor from food production and made it available for industrial and commercial expansion. In 1776, nearly 90% of the population was engaged in agriculture. After 200 years, in 1976, only 4% of the labor force was on farms and today it is even less than that. The productive efficiency of our agricultural system makes available to us an excellent diet by world standards at a very low cost. In addition to meeting our food and fiber needs, we have been the largest source of surplus food in a hungry world.

Technological developments in agriculture have increased the nation's agricultural output, but they also have created many problems for human resource development. These developments have displaced many workers from agriculture, workers who were either farmers or employed on farms. Many of these displaced workers have inadequate education and training for nonagricultural jobs. Moreover, the best-educated and most adaptable part of the rural population tends to move to urban areas, leaving behind many people who are unable to compete either with larger agribusiness or for rural industrial jobs. The President's Commission on Rural Poverty concluded in their 1967 report that "farm operator families without the skills or resources to keep pace in the farm technological race, and without offsetting nonfarm job opportunities, comprise a large part of the poverty problem" (President's Commission, p. 141).

You are aware of the several major structural changes which have taken place in the agricultural sector since World War II and which can be attributed partially to technological developments. These changes are (*a*) declining farm numbers; (*b*) increasing average farm size, and (*c*) increasing concentration of farm resources in fewer hands. The number of farms have decreased since reaching a peak of nearly seven million in the mid-thirties, dropping to 2.8 million in 1974 and again to 2.6 million in 1978. The rate of decrease in the

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Invited address.

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number of farms, however, has slowed from 2.7% per year in the 1950s to 1.1% in the 1970s (USDA 1979, p. 13). The increase in farm size is as dramatic as the decrease in number of farms. In 1974, the average farm size was 440 acres, more than double the average farm size in 1950. However, total cropland used in recent years has been almost identical to the mid-1930s total, 370–380 million acres (USDA 1979, p. 13). Thus, the farms that "disappeared" were incorporated into other farms.

The concentration of land harvested by larger farmers has increased over time. For example, in 1974, land harvested by all farms with 1,000 acres or more was 100 million acres, against only 60 million acres in 1964. Thus, in 1974, slightly less than 10% of the farms accounted for one-third of the land harvested in the United States (USDA 1979, p. 13). Concentration in agriculture has brought U.S. agriculture to a point where 6% of the total number of U.S. producers supply 53% of total sales. The 6% figure is comprised of an estimated 162,000 farms with sales of $100,000 and greater (National Rural Center 1978, p. 4). At the lower end of the concentration spectrum exists that group of small farms which is the focal point of this paper.

The Small Farm Situation

Changes in agriculture have blurred the once clear distinction between farm and nonfarm populations. At present there is no one definition of small farms which conforms to the accepted notions of what constitutes small and which is easily quantifiable for purposes of enumeration and statistical analysis. Although the gross farm sales per year ($20,000) criterion is the one most commonly used, it can easily be misleading because of variation in input requirements and the extent to which inputs are produced on the farm or purchased (West 1979, p. 49). It is recognized that defining small farms remains a problem in the agriculture field.

A large number of farms would be identified as small, regardless of the measure used. By the criterion, average annual sales of $20,000 and less, there were 1.8 million small farms in 1974. They represented 69% of the nation's 2.8 million farms, 27% of the land in farms, and 32% of the market value of machinery and equipment on all farms (USDA 1977). But the contribution of these farms to national agricultural output was lower than either the number of farms or control of resources would indicate, as they accounted for only about 11% of all the sales. Although these farms represent a relatively modest proportion of U.S. agricultural sales, they may prove crucial and of increasing importance to agricultural policy and the development of rural areas.

Small farms are located throughout the nation, with major concentration in the South followed by the North Central region. In a recent study (Orden, Buccola, Edwards), it was reported that fourteen southern states contained 794,148 small farms, nearly 50% of the Nation's small farms. In 1974, it was determined that over 50% of U.S. farms with annual sales under $5,000 were located in the South. In contrast, this region accounts for only 23.6% of farms with sales exceeding $20,000. Southern small farms with sales less than $20,000 accounted for over 40% of the value of the region's agricultural products.

Black farmers are concentrated in the southern U.S. and are virtually nonexistent in other regions. There were 59,371 farms, or 2.6% of the total, operated by black and other races in the United States in 1974. Of these, more than 80% are located in the sixteen southern states having 1890 land-grant institutions (Comer). The number of black farmers has declined at an alarming rate: from 1959 to 1974, southern black farms declined by 82%, leaving only 47,000 black operators in 1974 (Orden and Smith, p. 13). Of these black farmers, 92% operated farms with gross sales of under $20,000 per year, or they were small farmers.

The impact of the rapid and continuing technological advance in agriculture has not been basically different for blacks than for other farmers. But blacks often are concentrated in those classes and types of farming that are most affected by technology, for example, cotton and tobacco crops.

A still sizable number of black farmers remain in the agricultural sector, and their future in agriculture is bleak. Black farmers face all the same disadvantages as white farmers, but they also must contend with problems of racial discrimination in such areas as credit, land acquisition, and services provided by the agricultural agencies.

Small Farm Issues

The present structural concentration of agriculture and the contingent ill-fated position o

ıe small farmer have been created partly due) the bent in U.S. agricultural policy. The istorical bias toward efficiency over equity as deemed that technology and programs be ɔnducive to large-scale farming, and hence as induced concentration. Accompanying the ɹccessful concentration on large-scale agculture has been the public and private secɪr's neglect of problems and issues important ı the small-scale farm. The popular book, *'ard Tomatoes, Hard Times* (Hightower), .ys bare the fallacy in U.S. agricultural policy ıd the accompanying role of the land-grant ɔmplex creating a subculture of disadvanɩged throughout both rural and urban Amer:a. Research done in land-grant universities as mostly helped relatively larger farmers. [owever, most of the research was conducted 'ith the belief that benefits would filter down ıd small farms also would be able to use the :sults of the research conducted. This has not appened. Instead, the research has helped ıe concentration process even more. Only :cently, research projects specifically for nall farmers were initiated. In 1978, a report lentified sixty-seven projects with an estiıated twenty-seven scientists oriented toward nall farms. But these sixty-seven research rojects represented less than half of one perɜnt of all state agricultural experiment station :search projects (West 1979). Another point ıat I want to emphasize is that nearly half of l small-farm research projects are being conɹcted at the sixteen 1890 land-grant univerties and Tuskegee Institute. Most of the re:arch work in this vital area of small farms as initiated primarily at these institutions. his I believe was because of the reward sysm at larger agricultural universities, as work small farm areas was not considered imporınt nor publishable in recognized journals. lso, scientists at these institutions focused ɩeir research and extension efforts on larger ɔmmercial units because they have substanɜl political clout. Thus, the role of U.S. agcultural policy and agricultural universities ɩve given rise to both an undesirable level of ɔncentration in agriculture and an intolerable vel of human disadvantage across the United tates.

The most important issue concerning small ırmers is whether they can make a decent ving within the rural community. It has never ɜen proven that small farmers, given adeɹate incentives, cannot make a decent living om their farms. There are still 1.8 million farmers trying to make a living from their farms; but, under the prevailing circumstances, ever-increasing numbers of them are forced to seek off-farm employment. The demise of small farms in an area leads to the inevitable decline of the surrounding rural communities.

In addition to the costs to the individual, there are social costs indirectly borne by consumers. The costs of social services to support, train, and employ this population have overwhelmed many cities. The President's Commission on Rural Poverty concluded that many people "merely exchange life in a rural slum for life in an urban slum" (President's Commission 1967). Furthermore, there is concern about conglomerate corporate farms, which may prove to be less efficient than family-operated farms. Also there are obvious environmental problems associated with chemical-energy intensive methods of industrial agriculture.

Specific Problems Faced by Small Farmers

If future policies are to be outlined to slow down or reverse past trends, it is important to determine causes of major problems that small farmers face. During the early decades of this century, there were a few large farms, but mostly family-operated farms similar in size and with similar problems. This is not the case anymore. Because of the heterogenous nature of farms today, farm problems and their solutions are likely to vary. Problems generally associated with small farms are: (*a*) lack of information, (*b*) production inefficiency, (*c*) appropriate technology, (*d*) energy and input prices, (*e*) marketing systems, (*f*) tax structure, (*g*) land and its availability, (*h*) government policies and regulations, and (*i*) off-farm employment.

Lack of Information

Established means of communications have failed to work for low income farms. The role of disseminating research results has been primarily the responsibility of the agricultural extension service. In theory, extension programs are freely available to everyone; however, small farms do not seek help or use information from the agricultural extension service as readily as more successful farmers. Extension has claimed to work with most-re-

ceptive farmers on the premise that knowledge would "trickle down" to others. But surveys in Illinois and Indiana (Beer, p. 6), and in New York (Wardle and Boisvert, p. 24) have shown that this has not happened. There may be several reasons for this failure. One such is the reward system within the agency: "There has not been much status in working with poor people" (Ragland, p. 12). A recent study, entitled "Evaluation of Economic and Social Consequences of Extension Programs," yielded striking realizations in support of the above notion (USDA, 1980a). Furthermore, advisory boards of the extension at the local level generally are dominated by middle class farmers. Therefore, in many places this middle class clientele continues to command all the benefits.

Similar examples and opinions were expressed by Marshall and Thompson (p. 66). Apart from the above illustrations, extension programs of today face yet another difficulty in reaching the small farmer. In many states, extension programs at 1890 institutions possess a unique empathy for the small farmer and a special capability for addressing their needs. But they seem to be subtly diverted from rendering services by the dominant and better-endowed 1862 Extension Program because of fear of reprisal by the traditional clientele. Separate and unequal, the 1890 and 1862 extension programs cooperate under a strained relationship, and the latter manages to control program thrusts toward the small farmer and the disadvantaged clientele. Furthermore, most extension programs at 1890 institutions receive only federal monies and do not receive matching funds from state or local governments as extension programs at 1862 institutions.

Production Inefficiencies

Larger farms generally are perceived to have lower production costs and are more efficient in producing food and fiber, i.e., they have economies of size. Some recent studies, however, have suggested that "that role of economies of size in the expansion of farms may have been exaggerated" (USDA, p. 108). The advantages for large farms may be less than past studies suggest. Marshall and Thompson (p. 48) have distinguished three sets of economies of size. Those are (*a*) technical economies of size, (*b*) external economies related to the buying of inputs and the selling of outputs, and (*c*) external factors from government ag ricultural and tax policies and the way policie are implemented. They conclude that "techni cal economies do not appear to preclude th viability of small scale agriculture, at least i some cooperative and livestock areas." Pre liminary results of a study in west Tennesse by researchers at my university show tha large farmers are not more efficient in allocat ing their resources compared to small farmers This research tends to confirm that the ma jority of small farmers did not receive muc help or information from extension service (Singh and Bagi).

Appropriate Technology and Its Adoption

In 1939, labor constituted 54% of total input into U.S. agriculture. This proportion of labo in total inputs dropped to a mere 15% in 197 (USDA 1976). This structural shift is attrib uted largely to changing technology, but un fortunately many small farmers were unable t adopt this technology for their use. For th most part, modern agricultural technology ha focused on reducing labor requirements—th one factor that is adequate, if not in surplus on many small farms. Thus, in *Hard To matoes, Hard Times,* Hightower points ou that benefits from mechanization accrue dis proportionately to the rich and powerful, in cluding the stockholders of agribusiness cor porations and large corporate farms, and tha massive social costs are paid by displace workers, small-scale family farms, and societ as a whole.

Many small farmers must over-invest i equipment, as smaller farm machines are no available. This increases their fixed cost o production. Buying used equipment is an al ternative, but that also means higher costs i terms of repairs and maintenance. Hiring cus tom work is another alternative, where farm ers can make use of modern technology with out making large investments. In hiring cus tom work, one also hires labor, which a sma farmer might prefer to provide himself. Plant ing and harvesting have to be done in a limite time period, and small farmers may not be abl to acquire custom services at the appropriat time. The following factors have contribute to the slow adoption of technology by sma farms: (*a*) lack of capital, (*b*) lower educa tional levels and skills, (*c*) risk bearing ability (*d*) available labor, and (*e*) attitude towar change.

Marketing

Marketing is perhaps the most important consideration for any farm commodity or product. It is said to be the single most crucial element in a farmer's business, especially for those who deal in perishable commodities and who must contend with biological uncertainties. Lack of a market where small farmers can sell their produce is a growing concern.

The small farmer has been in the past and is yet confronted with major adjustments in the marketing arena. These adjustments are felt to stem from and be initiated in response to technological innovations, institutional changes, economic adjustments, and changes in consumer preferences. The market structure for most farm products has changed in response to the development of highly efficient communications and pricing systems. During the recent past, these technological developments brought about a dramatization of regional comparative advantage and resulted in the concentration of production in supply areas that could amass large quantities for volume shipment to large regional warehouses for distribution to retail chains. Market power has been concentrated among a few buyers. For example, over 70% of all food is sold through 15% of the retail stores (TVA, p. 11).

Smaller and more isolated producers have limited access to mass merchandising food distribution systems. Small farmers, because of their relatively low volume of sales, are severely restricted as to marketing alternatives. If they produce traditional products within the local area, they are limited in alternatives and bargaining strength because of low volume. Small producers, if they produce nontraditional products, cannot attract a market because of low volume. Therefore, they must develop their own market. Development of mechanical harvesting equipment and other such technological devices have placed producers at a comparative disadvantage in production, marketing, and processing. The market structure developed in response to technological advance tends to restrict market access for the small, isolated producer.

Energy and Input Prices

There is little information available on the relation between farm size and energy intensiveness. Correspondingly, we know little about the relationship between size and energy-related production costs or about how the effects of energy price increase would differ between small and large farms. But in the short run, it looks as if increases in energy costs would affect small farmers more by increasing input costs. The ability of large operators to lower input costs through quantity purchases and discounts may result in lower costs of production, which reflect imperfections in the input markets.

Tax Structure

Tax rules favoring farming in general, and backed by farmers as a whole, have brought differential impacts on small and large farmers. While the small farmer may benefit from tax advantages, the larger operations are able to take much more advantage of them. Many provisions originally were established to simplify record keeping for small family farmers and to provide tax relief to farms subject to widely fluctuating incomes. Currently, tax policies favor or subsidize the wealthy, whether his income comes from the farm or the nonfarm sector. Tax subsidies induce nonfarm investment and a separation of the ownership and operation of farms. Operators with higher nonfarm incomes benefit more, whether there is loss or profit. Tax benefits to those with larger income, especially large nonfarm income, have contributed to the rising demand for agricultural land and have helped push up land prices. Thus, tax provisions which benefitted the small farmer in the short run become obstacles to their survival in the long run.

Land Availability

Recent high land prices raise serious questions of the feasibility of land ownership by those we generally consider to be family farmers. Prices of farmland have increased more than 200% since 1970, and no one wants to predict the future (USDA 1980b). Most experts agree, however, that even at current prices, land earnings in the first few years after purchase may not be sufficient to pay principal and interest under typical loan terms. Therefore, one of the most pressing difficulties faced by the young, beginning farmer is to acquire control over a suitable land base.

Small farmers can increase their operation by renting agricultural land. However, some small farmers may experience difficulty ob-

taining and keeping rental agreements with landowners who turn over much of their prime land to larger operators. Black farmers face similar problems, but they are compounded by racial discrimination (Marshall and Thompson, p. 54). Black farmers not only face difficulty acquiring new land, by purchase or rental, but they also face problems holding their land. Partition sales, tax foreclosures, and other devices have caused the loss of much black-held land (Marshall and Thompson, p. 54).

Government Policies and Regulations

Small farmers are affected adversely by policies and by the way these policies are implemented by various agencies and institutions. More often these programs benefit the larger, commercial farms. For example, price and income policies have affected farmers in proportion to their farm size and volume of production.

Various government regulations also place small farm operators at a disadvantage. For example, rigid inspection regulations regarding processing of milk and slaughtering of animals often require expensive equipment and facilities that are unrealistic for the small farm operator.

Off-Farm Employment

Farm operators, particularly small operators, and members of their households are increasingly combining farm work with full- or part-time off-farm employment. In 1974, 30% of all farm operators reported 200 or more days off-farm work. An additional 10% worked at least 50 or more days off the farm. Data for 1977 suggest that this trend in multiple job holding is continuing (USDA, p. 270).

Off-farm employment is more common in the South than in other regions of the United States. Families operating small farms depend more on off-farm income than families on larger farms. Thus, availability of off-farm jobs affects the well-being of small farm families more than large farm families.

Policy Scenarios

Economics has been defined as the science of allocating scarce resources among competing ends. Ultimate ends to be achieved may be defined as utility, well-being, or quality-of-life. Efficiency is regarded as a requirement for the individual to receive the maximum amount of goods and services; therefore, efficiency has received much attention by economists, and its study is viewed as objective, precise, and respectable (Harper and Tweeten). Agricultural economic research in the United States traditionally has focused on farm production and marketing efficiency and has produced excellent results.

Recently, however, questions have been raised about just and fair returns for everyone, along with efficiency. Breimyer points out that sufficient attention has not been paid to the broader questions of social stability, employment, and rural community development (1973). Though there has been an increasing amount of research and discussion directed toward the problem of equity, there has not been enough. More and more people are concerned with issues that go beyond "efficiency." Americans certainly will maintain their interest in producing farm products more efficiently, but they also are becoming more interested in making sure that changes are made fairly, justly, and impartially (West 1973, p. 9). Future U.S. agricultural policies therefore, should reflect these goals.

The fundamental issue of the 1980s will be whether agriculture will preserve its identity (Breimyer 1979). The kind of agriculture that prevails makes a difference not only to farmers but also to rural communities and to all of us, as consumers. I need not remind you that it will make a difference to you as professional agricultural economists.

Public policies may have different effects on the economic circumstances of farms of different sizes. However, as Emerson points out (p. 951), public policies ought to be neutral with respect to size of operation. Obviously, present policies are not neutral, because program benefits are heavily skewed in favor of large farm operations and seem to discourage small farm businesses.

These facts and the problems identified in the previous sections of this paper suggest the need to address a wide variety of public policy issues. It is important, however, that we look at present policies and change them so that they work to the advantage of the majority of rural and urban population, not just the minority of business establishments.

Small family farms have ceased to be regarded as the essence of American agriculture.

he notion of what constitutes a small farm as changed a great deal over the past century, nd the farm within the reach of modest means as become less competitive (Brewster, pp. 5–47). It is urgent that we analyze the small rm issue in the context of agriculture as a hole. We need one uniform agricultural poly for large and small farms. It should recogize that America's 1.8 million small farmers e, in fact, farmers, and that they must be of s much concern to the USDA as are larger, ommercial farms.

The underlying goal of the policy should be eliminate injustices and inequities within he nation's economy, while increasing the conomic integrity and self-reliance of rural ommunities. Profit maximization and "cold looded" economic efficiency may not be the nly criteria for developing and evaluating rogram successes. While the number of poly options are virtually unlimited, the followg policy scenarios are suggested for easing onstraints that small farmers face.

echnological Constraints

abor is the most significant part of the reource base for a large number of small farmrs. Their technical problem is how to get the est possible return for their labor and mangement at an acceptable level of risk. There re two main solutions to this problem: resources can be shared to attain technical balance; and technology suitable for small farms can be developed, having a low capital-to-labor ratio.

The first solution, which involves buying and selling custom work, is being used by some farmers in some areas but is not a common practice. The possibility of buying and selling custom work should be explained and nformation about it should be made available. The feasibility of developing small coops also should be studied further.

Appropriate technology and equipment should be developed to meet the small farm abor and capital situation, versatile equipment appropriate to small acreages. Spreading the use of such equipment among farmers could have major economic benefits. Production of simple farm machinery, easy to maintain, and free of unnecessary gadgets that increase cost should be emphasized. More incentives, in terms of investment credits, may be provided to manufacturers who develop technology suitable for small farms. Investment credits would also encourage small farmers to acquire these machines.

In view of the current energy situation, serious efforts should be made by the USDA and other agencies to finance the research and development of energy-efficient technology. Small solar collectors farmers could build are examples of such technology.

Other areas in which small farmers require help include: (*a*) assessment of alternative systems of livestock production, handling, and marketing; (*b*) alternative systems of crop production, harvesting, handling, and storage, including opportunities for group efforts; (*c*) use of pesticides, and fertilizers, and (*d*) integrated pest management. Future policies may encourage universities to direct their attention to less resource incentive technologies, which may restore the relationship between people and land. Tax incentives, similar to current investment credit, might be appropriate to stimulate small farmers to invest in better brood stock, plant varieties, and record keeping, for example.

Marketing Constraints

Small farmers have special needs of the marketing system. They need to develop strong organizations to capture such external economies as quantity discounts and marketing strength, and to enable them to apply pressure to counteract institutional bias. Policies and programs may be developed to improve the existing system of marketing, and for research and development of alternative marketing systems for small farmers, including cooperatives.

Specifically, "we need better documentation of cost-production as well as selling to determine real market costs of the alternative types of direct farm to consumer marketing. Small farmers need technical assistance to help them become retailers as well as producers" (TVA, p. 162). Special efforts should be made to provide timely information to farmers, such as a referral service listing brokers who are willing to handle small accounts.

Measures should be taken to stabilize agricultural prices. Fluctuating prices affect small farmers more. International transactions should be handled in a way that benefits not only grain companies but also farmers. Encouragement should be provided for the establishment and success of cooperatives to serve marketing needs of small farmers. Loan

guarantees and technical assistance to new coops would be especially useful.

Financial and Economic Constraints

Small farmers face severe capital and land limitations, often arising from the general lack of credit. Only a few lending agencies currently have the ability and the mandate to serve low-equity or beginning farmers. Farmers Home Administration, as a public institution set up to work directly with the small family farm, should take the lead in changing the credit picture for small farmers. There is a feeling that institutions such as Federal Land Bank and PCA have become more conservative and are not willing to help small units get started. Some problems may represent serious oversight on the part of the U.S. Congress and, therefore, Congress should act to correct them. Furthermore, Farmers Home Administration may recognize cooperatives and their members as eligible borrowers. The loan limits on farm ownership and operating loans should be raised, but not to the point that it excludes small farms altogether.

Farmers do not have easy access to information such as (*a*) credit availability and the agencies, private institutions, and programs involved in extending credit to farmers; (*b*) how to apply for and obtain credit tailored for farmers; and (*c*) how to use credit wisely and efficiently. There is a need to develop communications between lending institutions and small farmers. Credit institutions may receive tax relief by increasing loan activity to farmers with gross sales below a specific limit. Agricultural Credit Act of 1978 should be encouraged and staffed to accommodate the needs of small farmers. The establishment of rural development banks also might be considered in order to provide credit to small farmers and promote rural development.

The main tax policy affecting the price of land is the tax preference on income derived from capital gains. Legislation should be enacted to end capital gains, tax-loss farming, depletion allowance, depreciation, and other loopholes which encourage land speculation. Land trusts may be encouraged to take the profits out of land speculation.

Information and Education Constraints

Special programs should be developed for making modern agricultural techniques available to small farmers. Programs should be tailored to develop their managerial and technic knowledge. Such programs for small farme generally have been successful in the Sout (Orden, Buccola, Edwards). One such pro gram to raise managerial and financial capabi ity is being implemented by Tennessee Stat University in western Tennessee. The initi success of this program indicates that sma farmers are responsive to programs wher paraprofessionals are used from the commu nity to implement a one-on-one education approach (Singh 1979). Such programs can b used to assist limited-resource farmers t make the most of their available resources an to communicate research results to them.

Efforts should be made to end the continue existence of discriminatory bias in publi agencies, especially the Cooperative Exter sion Service. The small farmer, both white an black, has not received an appropriate shar of public services. Extension should provid comparable services to small and large farm ers alike and establish an institutional env ronment in which the small farmer can exist For this, the reward system within the agenc may have to be changed. Extension shoul publish more literature dealing with sma farmer problems at a level they can under stand. Extension also should play an activ role in identifying small farmer research prol lems.

Lack of Research for Small Farms

Special policies should be directed toward research and training for small farmers by the land-grant system and concerned agencies. Research should be for everyone, although the larger goals of activities should be for the poor and needy. In the past, our research programs have emphasized efficiency. This concern must be continued; but, in light of our present concerns with poverty, environment, and the general quality of life, it must be moderated with equity for all people.

In the area of small farms, two types of research are needed. First, formulation of public policy is highly dependent on the quantity and quality of knowledge (data) available. If there is one issue about small farmers on which most people agree, it is the lack of reliable information about small farms and small farm families. Research is needed to develop a meaningful typology of small farms, indicating distinctly different kinds of small farms in terms of their resource endowments, aspira-

ons, sources of income, and other factors Madden and Tishbein). The second type of search is to recognize problems and find eir solutions (Tweeten et al.; Thompson; nd West 1979)

In general, three major research goals can e identified: (*a*) socioeconomic information bout the farmers and rural communities, (*b*) ypes of farming, and (*c*) extension methodology. Research results on problem identification and the aspirations of small farmers must e fully recognized and integrated into the ormulation of research priorities at the national level.

General Policy Considerations

Small farmers are a heterogenous group (Carin and Crecink; Tweeten and Popoola; Lewis). Through public policies, more human resource development options should be provided for rural people. Options should be provided for those who wish to remain in farming s well as for those who wish to leave farming ompletely or to become part-time farmers. Goals for public policy are to raise income and o reduce poverty. Farm income can play an mportant role in achieving this goal. In many reas, especially in the rural South, the need is or an increased number of income-generating pportunities. In some areas at least, maintaining job opportunities in farming (full or art-time) might be a more desirable strategy han remedial programs to deal with future isplacement.

Policy makers need to know the answers to uch questions as: (*a*) What kinds of nonfarm kills are most suitable for small scale and/or art-time farming? (*b*) How can these skills be eveloped? (*c*) How can off-farm work in the rivate and public sector be coordinated with mall-scale farming? And (*d*) what type of nanpower training programs can be successul in rural areas?

Appropriate manpower training programs hould be developed for rural areas. Industries, in both private and public sectors, hould be encouraged to locate in rural areas vhere unemployment is high. Such industries hould be required to employ local people irst.

Conclusion

Small family farms have been disappearing at an alarming rate. Support for small farmers, until recently, has not been forthcoming from any direction. Communities have invested in highways and shopping centers, destroying prime farmland and burdening existing farms with higher taxes. Government policies and regulations have placed the small operator at a disadvantage. Existing agricultural agencies, including extension, have not responded to the need of small farmers. As the number of small farms declined and migration from rural areas increased, the economic bases of these rural communities eroded.

Despite the large-scale displacement of small farmers in the United States since World War II, many still remain, and their welfare is an important concern not only to rural communities but to the nation as a whole. Increasing agricultural income on small farms is a reasonable policy goal, and it is in the best interest of the nation. Rationale for assisting small farmers is partly based on equity, or humanitarian grounds, and partly on efficiency, or economic grounds. The programs and subsidies to assist small farmers may be less expensive than welfare payments. Although not all small farmers desire to expand or have like goals, most would welcome an increase in income.

Special programs and policies must be tailored to help small farmers. Traditional approaches of delivery and incentives will have to be altered to deal with the unique sociological, psychological, technological, and economic needs of small farmers. "Symbolic pacification programs" will not solve the complex problems of small farms. Policies and programs should be developed to solve the problems of small farms simultaneously with the larger problems of rural poverty and unemployment. The goal of such policy should be to promote sustainability, diversity, and equity in a system of small farms and consumers, thus increasing the economic integrity and self-reliance of our rural communities.

Small farm problems are not going to go away, as they are part of major problems of agriculture and rural development and should be dealt with as such. These problems are going to increase; and, in the absence of solid, relevant research, it will be increasingly difficult to make good policy judgments. Therefore, as agricultural economists, you should address this most important problem and help remove the blight from our otherwise successful agricultural system.

Finally, there are two important principles which must inform the work of any who would

do substantive research on the small farmer's plight. The first is that you must respect small farmers as an entity. That respect will insure that a first-rate effort will be exercised on their behalf. The second principle is that the work of small farmers must be viewed as important and that they (the farmers) are professional in their approach to their work. This principle insures that those who work on the problems of the small farmer will listen with care to what they have to say. The small farmer's problem is not just a problem of social rectification; it is a problem of strengthening a nation. It deserves first-rate attention. Let us get on with the business of solving it.

References

Beer, Charles. "What's Happening to Political and Social Attitudes." *Proceedings of the Southern Farm Management Extension Committee Small Farm Seminar.* Lexington, Ky., Apr. 1973.

Breimyer, Harold F. "A Look at Emerging Economic and Policy Issues Confronting Southern Agriculture in the 1980's." *S. J. Agr. Econ.*, no. 1 (1979), pp. 7–9.

———. "Structure of Agriculture: The Policy Issue." *S. J. Agr. Econ.*, no. 1 (1973), pp. 1–6.

Brewster, David. "Federal Policy and the Small Farm, An Historical View." Washington, D.C.: NRC Small Farms Proj. Rep. No. 9, Nov. 1978.

Carlin, Thomas A., and John Crecink. "Small Farm Definition and Public Policy." *Amer. J. Agr. Econ.* 61(1979):933–39.

Comer, Sammy L. "Identification and Characterization of Small Farm Operator." Paper presented at AAEA annual meeting, Blacksburg, Virginia, 6–9 Aug. 1978.

Harper, W. M., and Luther G. Tweeten. "Socio-psychological Measures of Quality of Rural Life: A Proxy for Measuring the Marginal Utility." *Amer. J. Agr. Econ.* 59(1977):1000–5.

Hightower, Jim. *Hard Tomatoes, Hard Times.* Cambridge, Mass.: Schenkman Publishing Co., 1973.

Lewis, James A. "Implications of Alternative Definitions of a Small Farm." Washington, D.C.: NRC Small Farms Proj. Rep. No. 9, Nov. 1978.

Madden, Patrick J., and Heather Tischbein. "Toward an Agenda for Small Farm Research." *Amer. J. Agr. Econ.* 61(1979):939–46.

Marshall, Ray. *Rural Labor Markets.* Salt Lake City, Utah: Olympus Publishing Co., 1974.

Marshall, Ray, and Allen Thompson. *Status and Prospects of Small Farmers in the South.* Atlanta, Ga.: Southern Regional Council, 1976.

National Rural Center. *Toward A Federal Small Farms Policy (Phase I).* Washington, D.C.: NRC Rep. No. 9, Nov. 1978.

Orden, David, Steven T. Buccola, and P. K. Edwards. *Cooperative Extension Small-Farm Programs in the South: An Inventory and Evaluation.* Res. Div. Bu 153, Virginia Polytechnic Institute and State Unive sity, Apr. 1980.

Orden, David, and Dennis K. Smith. *Small Farm Pr grams: Implications from a Study in Virginia.* Re Div. Bull. 135, Virginia Polytechnic Institute a State University, Oct. 1978.

President's National Advisory Commission on Rural Po erty (President's Commission). *The People Left B hind.* Washington, D.C., 1967.

Ragland, J. L. "Attitudes of Extension about Low I come Farm Work." *Proceedings of the Southe Farm Management Extension Committee Sm Farm Seminar.* Lexington, Ky., Apr. 1973.

Singh, S. P. *Small Farm Research at Tennessee Sta University: A Description of Small Farm Develo ment Program.* Tennessee State University Bul Aug. 1979.

Singh, S. P., and F. S. Bagi. *Economics of Small Farm Characteristics, Resource Use and Productivity c Selected Farms in Tennessee.* Tennessee State Ur versity Bull., in press.

Tennessee Valley Authority (TVA). *Marketing Altern tives for Small Farmers.* Muscle Shoals, Ala.: N tional Fertilizer Development Center Bull. Y-14 Nov. 1979.

Thompson, Allen R. "Small Farms Definition and Polic Research Agenda: Discussion." *Amer. J. Agr. Eco* 61(1979):1949–50.

Tweeten, Luther, and Isaac Popoola. "Typology and Po icy for Small Farms: Agricultural Economist Versu Alternative Culturist." Paper presented at the Soutl ern Agricultural Economic Association meeting Hot Springs, Ark., Feb. 1980.

Tweeten, Luther, Wallace Huffman, Steven T. Sonk and Richard Rodefield. "Structure of Agriculture an Information Needs Regarding Small Farms." Wasl ington, D.C.: NRC Small Farm Proj. Rep. No. 1979.

U.S. Department of Agriculture. *Changes in Farm Pro duction and Efficiency, A Special Issue.* Washingtor D.C.: ERS Statist. Bull. No. 561, 1976.

———. *Evaluation of Economic and Social Conse quences of Cooperative Extension Programs.* Wash ington, D.C.: SEA, Jan. 1980a.

———. *Farmline.* Washington, D.C.: ESCS, Apr. 1980b

———. *Structure Issues of American Agriculture.* Wash ington, D.C.: ESCS Agr. Econ. Rep. No. 438, Nov 1979.

U.S. Department of Commerce, Bureau of the Census *1974 United States Census of Agriculture.* Washing ton, D.C., 1977.

Wardle, Christopher, and Richard Boisvert. *Farm an Non-Farm Alternatives for Limited Resource Dair Farmers in Central New York.* Cornell Universit Agr. Exp. Sta. A. E. Res. 74–6, July 1974.

West, Jerry G. "Agricultural Economic Research and Ex tension Needs of Small Scale, Limited Resourc Farmers." *S. J. Agr. Econ.*, no. 1 (1979), pp. 49–56

West, Quentin M. "Economic Research Trade-Offs be tween Efficiency and Equity." *S. J. Agr. Econ.*, no. (1973), pp. 9–12.

Comparing International Market Performance: Conceptual and Measurement Issues

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has become fashionable to compare the per-rmance of alternative marketing systems, articularly the grain-marketing systems of anada and the United States (McCalla and chmitz, Peltier and Anderson, Food West esource Consultants, Dever). This is not urprising given that there have been propos-ls to give a centralized agency, e.g., the ommodity Credit Corporation or an entity ke the Canadian or Australian Wheat Boards, ome degree of responsibility for marketing J.S. grain. Conversely, there are numerous roposals in Canada to reduce the marketing esponsibility of the Canadian Wheat Board CWB) and to alter other elements of the rain-marketing system.[1]

With such pressures it is appropriate and ecessary that performance comparisons be nade. But to do so requires that two questions e answered: how does one conceptualize per-ormance and how does one measure it? The bjectives of this paper are: (*a*) to present a rocess for arriving at a conceptual framework or comparing performance, (*b*) to suggest a onceptual framework in the form of perfor-nance objectives for comparing grain market erformance, and (*c*) to suggest a series of neasurable performance indicators.

Developing a Conceptual Framework

t is tempting to define performance as the evel of prices received by producers (as in most of the empirical work cited above) or to attempt to define it in terms of industrial orga-nization theory. Both are necessary; neither is sufficient.

Grain-marketing systems are complex, but there is a tendency to simplify their structural aspects. For example, the Canadian system is often regarded as Board-controlled while the U.S. system is regarded as open-market. However, the private trade and a futures mar-ket play the majority role in marketing oilseeds and domestic feed grains in Canada, and the private trade operates in the interna-tional market as agents of the CWB. The Commodity Credit Corporation (CCC) has an increasingly important role in the U.S. sys-tem. In both countries, the public sectors are important actors in grain marketing through pricing, trade, food aid, and transportation policy as well as grading, provision of market intelligence, and research. Obviously, the na-ture of public policies in each country is sub-stantially different. But just as obviously, both systems contain private, quasi-public and pub-lic institutions. The differences are of degree and specific function.

The mixed nature of both countries' grain-marketing systems, as well as those of other countries, makes it mandatory that the struc-ture of the system be defined and thoroughly understood in undertaking comparative analy-ses of performance. Furthermore, given the increasing role of the public sector and the multiobjective nature of public policy, the definition of performance cannot be restricted to a conceptual framework that includes only variables internal to the grain sector. Public policy is developed by and has its impacts through a series of economic and social trade-offs. For the grain sector, these trade-offs occur not only among entities that pro-

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[1] Some of the most recent include: (*a*) moving responsibility for eed grain exports to private traders, (*b*) reducing Wheat Board ontrol of rolling stock, (*c*) removing the Wheat Board's power to stablish delivery quotas for nonboard grains and oilseed, (*d*) ubstantially altering the administration of benefits under the Crow's Nest Pass Agreement for freight rates.

duce and handle grain and among the various species of grain and oilseeds, but also among closely related sectors such as the domestic livestock complex, and upon matters of national concern such as international balance of payments or domestic employment.

Hence, it is not sufficient to ask which system returns the highest prices to producers nor to ask which system provides the least productive or pricing inefficiency. It is possible that a system is willing to sacrifice on these variables in order to gain elsewhere. Similarly, it is not sufficient to relate concentration ratios to profitability as is the wont of industrial organization practitioners. The latter question is irrelevant to quasi-public institutions such as the CWB or the CCC. It is both necessary and sufficient to form a concept of the sector's (or subsector's) objectives from the public point of view as well as from the view of private market participants.[2]

To formulate this concept, a process suggested by Shaffer and Jesse is adopted. The logic of this process is as follows. First, we must recognize that the marketing system is made up of many participants. For the grain sector these include: domestic consumers of food grains, domestic consumers of feed grains, foreign consumers of grains, grain producers, the handling and transport subsector, and the public sector which has expectations about the grain sector's effects on foreign exchange earnings and economic growth. Second, each set of participants has expectations or objectives of the grain sector, and these objectives may be conflicting. Third, many of the issues that relate to changing the structure, conduct, or regulatory environment of the grain sector are public policy issues. The positions of policy makers on various issues are likely affected by their (policy makers') perception of the current system's performance on the various objectives.

Given the foregoing, the framework for comparative analysis of performance consists first of specifying the expectations of market participants as generalized objectives. These are expressed in terms that are value laden, not prone to measurement and, in some cases, embody multiple concepts. To add specificity, the second step is then to define a set of performance indicators that represent the various objectives. The principal contributions of these indicators are to delineate the vario concepts embodied in the objectives and assist in moving closer to measurable va ables. The final step is to specify a set quantifiable measures that represents each the performance indicators and provides t basis for analysis.

[2] Bruce Marion made this point clear in commenting on a related paper (Martin 1979).

Objectives, Indicators, and Quantifiable Measures

The first four objectives (table 1) are intern to the grain sector and include concepts sim lar to those included in industrial organizatio In objective I, domestic consumers of foo grains are treated separately from consume of feed grains and foreign consumers (see b low). The indicators delineate the two comp nents of the objective and the quantifiabl measures are straightforward.

Objective II contains several concepts. Th first, emanating from the desire to stimulat production, relates to the level, stability, an adequacy of producer returns. The secon price spreads and marketing costs, is co cerned with the operational and pricin efficiency of the marketing system.

Because objective II includes the reflectio of consumer preferences, the third indicator market signals. The first three measures co cern product grades. The relevant question are: Are there a sufficient number (or to many) and sufficiently understood grades t reflect qualitative factors? Is the integrity c grades maintained throughout the marketin process so that those attempting to respond t qualitative factors are rewarded for so doing' Do grades reflect buyer preferences?

A third measure associated with market sig nals is the correlation between world an domestic prices. This variable should indicat how well the domestic market reflects worl demand so output and consumption can re spond.

A fourth concept is the response to chang in the preferences of consumers. For grain exporting countries, the major potentia changes in preference lie in wheat relative t coarse grains, grains relative to oilseeds, milling relative to feeding quality wheat, and traditional relative to new crops. Changes in preferences should be apparent in trends in international demand (i.e., trends in trade) for the relevant products. Where structural change is apparent, the measures of response are trends

production or acreage of the relevant prod- ts and production or acreage response to ɔrld prices.

Productivity (objective III) is in many ways e mirror image of the cost considerations in B. However, productivity ratios often can be ɜasured more easily than costs, and focusing an explicit productivity variable assists in parating changes in costs due to changes in oductivity from those due to other factors. ıch measure only partially represents the derlying concern. An alternative but ficult to obtain measure of productivity and ficiency that likely should be considered is a ɔntier efficiency measure as suggested by ırrell.

An area of central concern regarding the olution in grain-marketing institutions is uity; in fact, one of the stated objectives of ɜ Canadian Wheat Board is to ensure equi- ɔle market access to producers. Equity con- lerations of course also revolve around in- me distribution. Hence, the indicators and antifiable measures for objective IV are di- led into categories reflecting market access d income distribution.

A major issue in the debate over board- rsus nonboard-marketing systems is their ility to penetrate and maintain export mar- ts in various countries. In particular, there concern that, in a world wherein purchases ɜ made increasingly by state or quasi-state- ıding corporations, a decentralized, non- ard-marketing system has disadvantages chruben). The corollary is that a centralized lling system with greater control over ouput, ices, and transportation has greater ability negotiate long-term contracts—particu- ly with the centrally planned economies. ɜnce, accessing alternative foreign markets an objective (objective V), and the mea- res are intended to reflect performance ereon.

A related issue is the ability of the exporting stem to respond to short-term market op- rtunities (objective VI). Can a system an- ipate market opportunities and deliver oduct when opportunities arise? To measure is, the exporter's share of world trade when ɔrld trade or world price differs from trend is ggested.

Objectives VII–IX relate to the interface tween the grain and livestock sectors, as ɜll as the contributions of the grain sector to ɜ balance of payments, employment, and vestment. The two general concepts in these three objectives are intertwined. The grain sector provides an input for livestock production, but it also competes with the livestock sector for resources. If the grain sector is organized such that the domestic feed market is discriminated against in favor of the export market, then resources will be misallocated and the domestic economy may forego value added, employment, multiplier, and foreign exchange benefits of increasing livestock production. Devine has indicated that, for Canada, the value-added and multiplier effects of livestock production and processing are greater than for grain production and handling. Hence, it is necessary to consider foreign exchange earnings, investment, and employment in both the grain and livestock sectors. The final three objectives, their indicators, and measures attempt to do so.

Concluding Considerations

There are a number of issues related to making operational and then interpreting the results of analysis using the conceptual framework presented here. One is the measurability of the quantitative measures and the degree to which each measure represents the underlying indicators and objectives. Clearly measurability is variable. Some characteristics are relatively easy to obtain from secondary sources. Some, even if available from secondary sources, are difficult to express on a comparable basis. For example, a study underway at the University of Illinois (Lonergan) is attempting to compare export (West Coast and Great Lakes) and farm prices for wheat in Canada and the United States, with price spreads relative to handling and transfer costs. Some of the difficulties encountered in making price comparisons are the following: export prices for each country are reported at different positions in the marketing system; there are doubts about the representativeness of reported prices; variations appear in grade definitions, protein content, moisture content, and dockage specifications in the two countries; and farm prices are required to be calculated at points which are a comparable distance from the ports.

In many cases secondary data are not available, and substantial conceptual and empirical problems would be incurred in obtaining primary data. For this reason, alternative quantifiable measures have been suggested for

Table 1. Performance Objectives, Indicators, and Quantifiable Measures

Objective	Indicator	Quantifiable Measure
I	To assure an abundant supply of food grains to domestic consumers at economical prices.	
	A. Level and stability of available supplies	1. Trend in available supplies 2. Variation around trend in available suppl
	B. Level and stability of consumer prices	1. Trend in consumer prices 2. Variation around trend in consumer price 3. Consumer prices relative to CPI, WPI, o substitute prices
II	To stimulate and facilitate the efficient production and distribution of that combination of products and related services which best reflect the preferences of consumers and the real relative cost of production.	
	A. Level and stability of producer prices	1. Trend in producer prices 2. Variation around trend in producer price: 3. Producer prices relative to costs
	B. Price spreads and marketing costs	1. Price spreads—spatial and at alternative market levels 2. Transport, handling charges, and costs 3. Spreads relative to costs
	C. Market signals	1. Number and type of product forms and grades 2. Grade aggregation at final sale level 3. Buyer preferences compared to existing grades 4. Correlation between world and domestic prices
	D. Adaptability to structural change in demand	1. Production or acreage of new or differentiated crops 2. Output or acreage response to changes ii world price
III	To increase productivity.	
	A. Productivity	1. Trend in output or value added per unit labor/capital 2. Output relative to industry capacity 3. Turnover or turnaround ratios for variou: factors 4. Rate of technology adoption
IV	To distribute opportunities and rewards equitably.	
	A. Income distribution	1. Grower returns and marketing margins relative to production and marketing cost 2. Income distribution among owners of fac inputs
	B. Market access for producers	1. Price variations among producers 2. Sales restrictions 3. Carry-over as a proportion of production
V	To gain access to international markets.	
	A. Sales to alternative countries/regions	1. Trend in exports by destination 2. Trend in market share by destination 3. Trend in exports by destination relative 1 (exporter's) domestic production
VI	To respond rapidly to short-term market opportunities.	
	A. Response to change in demand	1. Share of world trade when trade exceeds trend 2. Share of world trade when world price exceeds trend
VII	To encourage stable growth in livestock production.	
	A. Feed grain prices and availability of supplies to livestock producers	1. Trend in prices 2. Variation around trend in prices 3. Variation in on-farm inventories of feed grains

able 1. Continued

jective	Indicator	Quantifiable Measure
	B. Livestock production	1. Trend in livestock production 2. Variation in trend around livestock production
II	To encourage foreign exchange earnings in the grain and livestock sectors.	
	A. Foreign exchange earnings	1. Trend in foreign exchange earnings for grains 2. Trend in foreign exchange earnings for livestock products
	To provide growing and stable investment and employment opportunities in the system.	
	A. Employment in grain handling and livestock processing	1. Trend in employment 2. Variation around trend in employment
	B. Investment in grain handling and livestock processing	1. Trend in net investment 2. Variation around trend in investment

me objectives; although in many cases what measurable is likely not as good a represen-tion of the objective as what is not. For ample, a frontier measure of efficiency and oductivity as suggested in the text is a better easure than the comparison of costs and mple productivity ratios suggested in table 1.

A second and related issue is that of assign-g causality where differences in performance cur. This is illustrated by two studies (Mar-n, Wilson and Anderson) which have at-mpted to compare performance of the Cana-an and U.S. systems on objectives V and VI. oth studies showed that the U.S. system is perior on both objectives. However, there e several hypotheses regarding the opera-onal and pricing attributes of the two systems hich could have caused the differences in rformance. Furthermore, some people in estern Canada contend that Western Cana-an climate limits production response and us the ability of the Canadian system to gain d hold international markets as well as its ility to respond to market opportunities. urther analysis is required to sort out the uses.

A third issue is that many of the measures not provide norms; they are merely de-riptive. In no case, for example, where vari-ility of a series is suggested as a perfor-ance measure, is it suggested that a given egree of variability is good or acceptable.

In response to the latter two issues and in fense of the framework suggested, the ob-ctive of the exercise is to provide a frame-ork that is diagnostic, as Bressler and King ve called for. Analysis of comparative eco-mic performance is done to provide policy akers information on the strengths and weaknesses of alternative systems and to determine areas in which performance of a given system can be improved. For many of the objectives of a grain-marketing system, norms cannot be determined analytically. However, comparison across systems using this framework can provide information on relative performance in various areas. It also can point out in which areas performance diverges the most, so that efforts can be productively focused to determine the causes, possible cures, and the impacts of alternative cures on other performance measures. In a world wherein business and public policies are made in response to conflicting objectives, perhaps this is what we should strive for.

References

Bressler, Raymond G., Jr., and Richard A. King. *Markets, Prices and Interregional Trade*. New York: John Wiley & Sons, 1970.

Dever, Donald A. *Features of U.S. Grain Handling and Transportation System Which May Hold Potential for Canada*. Winnipeg: Canada Grains Council, Apr. 1980.

Devine, D. G. "The Value Added Concept: The Relative and Regional Merits of Producing and Processing Grains, Livestock and Meat in Canada." *Proceedings of National Pork Seminar*, pp. 25–60. Ottawa: Agriculture Canada, Oct. 1977.

Farrell, M. J. "The Measurement of Productive Efficiency." *J. Royal Statist. Soc.* 120(1957):253–81.

Foodwest Resource Consultants. *U.S. Grain Handling and Transportation with Selected Comparison to the Canadian System*. Report for Alberta Department of Economic Development, Edmonton, June 1979.

Jesse, Edward V. *Measuring Market Performance: Quantifying the Non-Quantifiable*. WP-15, University of California, Davis, Mar. 1978.

Lonergan, N. L. "A Comparative Analysis of the Grain Handling and Transportation System in Canada and

the United States." M.S. thesis, University of Illinois, forthcoming.

Martin, Larry. "Comparing Performance of Alternative Marketing Systems—A Suggested Approach with Special Reference to the Grain Markets of Canada and the United States." Paper presented at NC-139 technical meeting, Moscow, Idaho, Aug. 1979.

———. "Performance and Problems of the Canadian Grain Export System." Paper presented at Illinois Grain Dealers Conference, Urbana, 21–23 Jan. 1980.

McCalla, Alexander F., and Andrew Schmitz. "Grain Marketing Systems: The Case of the United States versus Canada." *Amer. J. Agr. Econ.* 61(1979): 199–211.

Peltier, Keith, and Donald E. Anderson. *The Canadi Grain Marketing System.* Dep. Agr. Econ. Re N0130, North Dakota State University, 1978.

Schruben, L. W. "Grain Marketing Methods in t U.S.A.—The Theory, Assumptions, and Approach *Amer. J. Agr. Econ.* 55(1973):800–3.

Shaffer, James D. "On Performance Accounts or Wh Variables Are Important in Evaluating the Organiz tion and Control of the U.S. Food Productic Distribution System?" Paper presented at NCT-1 technical meeting, Nov. 1972.

Wilson, W. W., and D. E. Anderson. "The Canadi Grain Marketing System." Paper presented at AAE annual meeting, Urbana, Ill., 26–30 July 1980.

armer Cooperatives in International Grain nd Oilseed Markets

'vin R. Bunker and Michael L. Cook

recent years, several grain and oilseed pro- :er cooperatives have expanded operations nternational marketing. Some of these ex- 1sions include the purchase of part of Alfred Toepfer Co., an international commodity ding company, by several North American l European cooperatives; the expansion of banese cooperatives into U.S. grain- ndling and storage functions; integration of lian cooperatives into processing industries developing countries; and the enlargement one interregional cooperative into the rth largest U.S. grain exporter.

Ve suggest that these innovations are pre- inary signals of a structural change in inter- ional grain trade. Our objective is to exam- the changing role of farmer cooperatives in complex international arena of grain and seed trade. Four phenomena are explored: farmer cooperative location in the world bean, coarse grain, and wheat market ıcture; (*b*) market share trends of U.S. peratives at the local, regional, and export els; (*c*) the increasing importance of foreign peratives in the international grain trade; l (*d*) factors that might constrain or en- ıce the growth of cooperatives in the world in trade.

rld Grain Market Structure

ain marketing cooperatives play a sig- cant role in most market economies. In t-handler functions of grain assembly, stor- , and elevation, Knutson, Cook, and Spor- er estimated that cooperatives handle 45% the grain produced in exporting nations. In the higher-risk functions of export marketing, activity is more limited, with cooperatives directly marketing 9% of the world grain exports and 10% of the imports. The greatest cooperative participation in grain export trade exists in Argentina, Brazil, France, and the United States. Grain-importing countries which have substantial cooperative involvement include Japan, the Netherlands, Federal Republic of Germany, and Belgium.

Notable structural differences exist in the international grain market (table 1). High levels of country concentration exist in soybean and coarse grain exports, while lower levels of concentration prevail in imports. State trading is relatively unimportant. International trade in soybeans and coarse grains is

Table 1. Comparison of Grain Importing and Exporting Country Concentration Ratios by Commodity and by Proprietary, Cooperative, and State Trading Market Shares for the Largest Eight Exporting and Importing Countries, 1977–78

	Soybeans and Meal	Coarse Grain	Wheat
	--------	(%)	--------
Exporting countries:			
Four-country share	100	79	86
Eight-country share	100	86	95
State-trading share[a]	0	6	27
Proprietary trade share	90	83	65
Cooperative share	10	11	8
Importing countries:			
Four-country share	45	47	36
Eight-country share	67	72	51
State-trading share	0	21	90
Proprietary trade share	80	67	10
Cooperative share	20	12	0

Source: Cook, Knutson, Sporleder.

[a] State trading, proprietary, or cooperative share is the estimated percent of the total volume of direct grain exports or imports by state traders, proprietary firms, or cooperatives for the eight largest importing or exporting countries.

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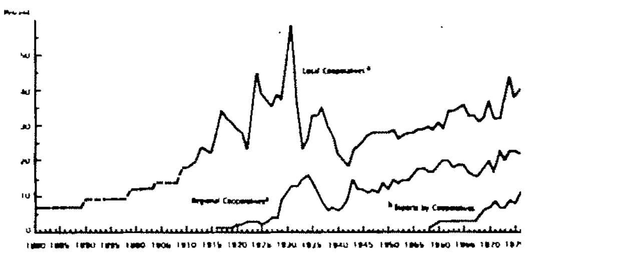
dominated by the proprietary grain-trading companies in exporting, importing, and market intermediary roles. The market shares for cooperative exports of soybeans and coarse grains are estimated at 10% and 11%, respectively, and their imports at 20% and 12%.

The international wheat market structure is considerably different from that of other grains. Exporting country concentration remains high, yet importing country concentration is relatively lower. State traders are estimated to account for 27% of the exports and 90% of the imports of wheat. Cooperative involvement is relatively small with 8% of the exports and no significant volume of imports.

U.S. Grain Cooperative Marketings

The entry of U.S. cooperatives into grain marketing initially occurred at the local, first-handler level during the mid-1800s (fig. 1). Prior to 1880, efforts at establishing grain-marketing cooperatives were scattered and usually unsuccessful.[1] During the 1880s, efforts were more organized and widespread but still largely unsuccessful. The "maintenance clause" introduced in 1890 provided financial stability, and thereafter local cooperatives commenced a period of rapid growth. The "maintenance clause" provided that members pay the cooperative a fixed fee per bushel marketed, regardless of to whom his grain was sold, for the purpose of maintenance of the cooperative. By the mid-1920s the share of grain marketings originated by local farmer cooperatives ranged from 35% to 45%. Several authors have described these early efforts at farmer organization as actions resulting from adverse economic and social conditions (Federal Trade Commission; Gardner; Knapp 1969; U.S. Congress).

To ameliorate the effects of the adverse economic conditions in agriculture during the 1920s, Congress enacted the Agricultural Marketing Act of 1929 establishing the Federal Farm Board. A chief objective of the Board was to stabilize product prices by assisting cooperatives chiefly through loans to finance storage operations. Under this program, local cooperative grain-marketing shares expanded sharply in 1930–31. But, after the failure of the



[a] Grains and oilseeds marketed by cooperatives as a percent of farm sales. Estimates prior to 1910 are based on dates organization as reported by established cooperatives in 1924
[b] Direct exports of grains, except rice, and oilseeds by coop tives as a percentage of U.S. exports of these commodities. Sc indirect exports included from 1960–1970.

Figure 1. Share of grain marketings by U local, regional, and export cooperatives, 188 1976

Federal Farm Board and its stabilization forts, the share of marketings handled cooperatives declined to an eighteen-year lo Since then, the share of grain marketings local cooperatives has increased gradually 40% by the late 1970s.

Thus, the development of local cooperativ in grain marketing began with a period of e perimentation and learning and, later, a peri of rapid growth. Both periods are chara terized by adversity felt directly by farmers marketing their grain. The adversities includ unacceptably low prices, monopolistic pra tices by existing merchants and rail lines, u fair or discriminatory treatment, and lack services offered to producers.

Since World War II, adversity does not a pear to be as important a factor in grain coo erative market-share expansion. We sugge that growth in this period is more a function action driven by opportunity, resulting fro aggressive management.

Development of U.S. regional grain c operatives follows a pattern similar to th of the local cooperatives; that is, there is period of experimentation with alternati marketing organizations lasting from abo 1915–25. From 1925–35, regional cooperativ developed rapidly, stimulated by the Feder Farm Board experiment. Growth in the ma ket share since that time has been much mo gradual. Several writers have described t adversity farmers perceived in not being ab effectively to market the grain sold to loc cooperatives without some control over ou lets in the terminal markets (American Ins tute of Cooperation; Gardner; Knapp 197 U.S. Congress; and U.S. Department of A riculture).

[1] A notable exception was the establishment of numerous "Patrons Joint Stock Companies" between 1872 and 1875. With the weakening of the Granger movement and improved marketing conditions, most of these elevators failed.

nternational Middlemen in Grain and)ilseeds Markets

oseph Halow

ears ago in a college literature course our rofessor explained that some historians disuted the fact that the *Iliad* had been written y Homer. They contended there were indicaons it had been written by someone else, hose name, oddly enough, also was Homer. am frequently reminded of this absurdity hen critics of U.S. agriculture speak disaragingly of middlemen in agricultural mareting and processing, indicating that they are ıe bad lot who intervene unnecessarily beveen the farmer and the consumer to exact a ofit. They suggest that this function be performed by representatives of the farmer, as in rmer cooperatives, or through the formation other separate groups to market and process the commodities for the farmer.

The concept of the farmer performing the ntire function is so unrealistic as to merit tle comment. It would suggest bridging the nturies and returning agriculture to a system ore compatible with Homer's time than ırs. It is ludicrous to think of marketing grain a raw or unprocessed state at farmers' marets such as those in which produce is somenes sold. Of course, wheat is marketed imarily as bread and other flour products, ıd corn is marketed principally as meat. And takes a great many people with a variety of ills to transform those grains into products ıd to bring them to the points where they are eeded. Wheat has relatively little value on e farm if someone "out there" does not ant it or if it cannot reach the consumer. nd, the consumer does not want wheat as ain, he wants it as finished product in the permarket. Soybeans are almost worthless thout expensive processing. And the farmer not in a position to perform these processing ıd transport functions because he has neither e facilities nor the time and contacts.

The puzzling part of the suggestion to form new groups or cooperatives to process and market grains is that it changes nothing, for it merely exchanges one commercial group for another. Anyone who performs these functions immediately becomes a middleman, and he is, therefore, subject to the same risks and conditions now faced by those who market and process grain. The one major difference is a negative one, for almost all who attempt to crash into the grain-exporting field know relatively little about it other than that it looks like a good business. This conclusion is reached principally because they are impressed by the volume moved.

The individual or firm that markets grain becomes more the agent of the farmer, for his function is an extension of the marketing chain which begins when the farmer sells the grain to the country elevator. Considered in this fashion, there can be no separation into "international middlemen" and, one assumes, "domestic middlemen," for they are an integral part of a system, as important as the farmer himself. From the farmer to the firm that loads the grain on a vessel for export, all are part of the marketing chain. And that marketing chain has become international because the percentage of U.S. grain in the export market is already over half of total annual sales, and growing.

The concept of a middleman who intervenes between the farmer and the ultimate consumer, profiting in the act, is an old socialist argument, one which ultimately leads to government-controlled monopolies. The other marketing alternative is to turn to government, for, given the impracticality of the other suggestions, one then must seek a group of well-meaning, honest, astute and omniscient individuals, who are without any vested interest in the function they are performing. They are, of course, always exceptionally gifted, for they assume a superior knowledge and understanding of the function they are to perform automatically when the title is conferred on them.

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A "marketing specialist" becomes one immediately when he is promoted to that post, even though he may have been an accountant before that.

The way to a socialistic marketing system is paved with a criticism of the free enterprise system. As agriculture assumed greater importance during the past decade, there has been a constant complaint that "something had to be done" to solve the problems in agriculture, although an unbiased observer might have difficulty understanding what all the shouting is about. For, far from a poor or even a mediocre performance, U.S. agriculture has performed nothing less than brilliantly.

Ten years ago U.S. exports of wheat, feed grains, and whole soybean totaled 46.5 millions tons. This year, U.S. exports of those commodities are forecast to be about 127 million tons or, 273% of the quantity exported a decade earlier. The total world figures for the period are 108 million tons ten years ago and about 213 million tons this marketing year, or not quite double the quantity traded a decade ago. U.S. performance is clearly better than that of any, or all, of the other exporting countries.

Agricultural trade has been the best foreign exchange earner for the United States, providing us with a favorable net balance of trade of about $14 billion annually. There is no other sector of the economy [illegible]as performed so well. If they could[illegible] we [illegible] enjoy a favorable balance of tr[illegible] and payments, a thriving economy without [illegible]flation, and the international prestige and influence we took for granted when we had all those things.

The part of the farmer in the agricultural miracle is clearly understood and recognized. Less understood and appreciated, however, is the role the rest of the system plays in this outstanding performance. The exporter provides many of the facilities in which grain is collected after it leaves the farm. He also provides the facilities through which grain moves to port, and the facilities through which it is loaded. He seeks the export markets, and he assumes the risk in making and delivering the export sale. Such risks are both economic and political, and the political risks can be encountered in both the United States and other countries. It is the exporter who continues to invest whatever profit he may have made in new facilities for handling and moving the grain, for if he did not there could not have been the expansion we have witnessed durin these past ten years. Grain is worthless on th farm, and the farmer who continues to buil up a surplus because his grain cannot b shipped is inclined to plant less. Because th exporter invests in the future, he must als evaluate the market, analyzing not only i current but also its future potential.

The exporter does all of this, of cours because he does hope to make a profit in h operations—if he did not have that as an in centive, he would not be inclined to undertak the necessary investments and risks, and th industry and nation would be the loser.

The concept of profit also has been inacc rate and at times distorted, but this also is keeping with the liberal or socialist philosoph which lies behind the attack on free enterpris in agriculture. Profit is, first of all, one of th most basic incentives. It is certainly a hypo risy to criticize business' interest in profits the critic strives for promotions and incom increases in his own profession. Books hav been written criticizing the grain exporter drive for profits. Yet the prices demanded f such books indicate that the authors also ho for a share of the book sale profits. To this er the authors have attempted to make the books interesting, even if in so doing the pr sentation falls short of—or is contrary to—th facts.

Export profits are not always realized an certainly not to the extent generally believe A grain exporter remarked recently that du ing his early training, his employer had to him that it does not require much merchandi ing ability to buy a bushel of grain and sell for a little more than its cost. Real merchandi ing ability, he was told, is to buy a bushel grain and sell it at a price a little under the co to the seller and still make a profit! And this where most of the profit has been derived grain exporting.

An example is provided by the experienc of farmer cooperatives in some of their initi direct sales efforts overseas. They foun ready buyers abroad, all of whom also hope to avoid the so-called middlemen and th obtain grain at lower prices. To their di may, however, the buyers learned quickly th when they received offers against their te ders, prices offered by the cooperatives we appreciably higher than the prices other e porters offered. Their dismay was parallele by their amazement because the exporter

ho had purchased grain from the coopera-ves, were able to offer it at prices lower than ose the cooperatives were asking. Coopera-ves have learned to be more aggressive and ıve made great inroads into direct export les, so much so that one of them is now nong the top five firms in the nation. The ample illustrates clearly that profits are ade in management, not necessarily because the type of mark-up customary in other anches of business.

Because the exporter does have a vested terest in agriculture, he has the incentive to rform his function well. The argument sed frequently that government officials ay not confer with exporters because they ve vested interests is absurd on two counts: rst, because those who have a vested inter-t in an industry are those who know most out it and who are most interested in its elfare. It is offensive and inaccurate to sug-st that those who have vested interests are rsuing those interests at the expense and to e detriment of the nation. It is also absurd cause of the implication that those not in the dustry, such as government officials, do not ve vested interests. Almost everyone has a sted interest; almost everyone is interested making a profit; almost everyone is in-rested in being promoted. Those without ch ambition are not those who are making y serious contribution to the economy and e nation. Of course, there are a few nuinely altruistic people in the world, and ey do make a commendable contribution, t they are exceptional, a small percentage of e population.

A North Dakota wheat farmer eloquently pressed his concept of profit when he heard at a high level government official had indi-ted that there were farmers who agreed with e administration's action calling an embargo sales to the Soviet and then there were ners who would do anything for a buck. The mer retorted, "Of course we do it for a ck! Why does he think the farmer farms? es he think we do it because we like to oke the hogs!"

The concept of a middleman, as held in me circles, actually could be more aptly plied to government and government inter-ntion in agricultural marketing. This is not deny that government has a function to rform in agriculture. Its function should be aid and not to replace or direct. If having a constant source of food available for the people is a responsibility of the government, then government has an obligation to provide facilities to the farmers for planting a crop. Government does have a responsibility for keeping the agricultural community advised on conditions in agriculture, to aid farmers and agribusiness in making plans for food production and its movement. Government does not have a role in restricting the marketing of food except in national emergencies or in instances when there may be an inadequate supply of food for the nation. There are many persons who do not feel that these conditions have been met during the past decade, during which time there have been several embargoes, each of which was later termed not to have been necessary and none of which was ever considered to be particularly successful in achieving whatever purpose may have been given as the reason for its institution. One embargo against certain Eastern European countries was, in fact, said to have been the result of a power play between the State Department and the Department of Agriculture!

If the middleman is someone who comes between the farmer and the ultimate consumer and does so for a profit, then it fits instances when government goes beyond the function of providing assistance and begins to exercise a control over the movement of a commodity which it does not [illegible] (If someone does not believe government agencies do not make direct profits, he should check the activities of the Federal Grains Inspection Service which has produced a tidy profit of about $16 million in approximately two years of operation. And this in an area in which government does have a legitimate function but also has become overzealous.)

A more subtle form of profit is one in which government employees enhance their own positions and/or provide positions for others through intervention in the markets. An even more subtle form is through the political use to which agriculture may be put and the benefits which may be derived from such action. A blatant form of middleman intervention in the market is provided by the government's signing of a bilateral agreement with Mexico for the sale of certain amounts of grain. In doing so the government provided nothing other than an assurance to Mexico that the U.S. government would not impose an embargo on those sales. Such an assurance would not be

necessary if the government were not in the business of embargoing grain sales in the first place. Nor has the government's intervention in this business brought anything to the agricultural community or to the nation, because the sales would have taken place without the government's intervention. That is, whatever benefits there are in the sales would have taken place completely without the government. Only the government would have benefited, through whatever political advantage the government may have derived from the transaction.

The worst part of having a government middleman is that the government does not compete fairly for markets—actually it does not compete at all, so neither buyer nor seller has the benefits competition brings to a market. Government merely monopolizes business when it assumes a commercial role: there is no competition to bid up farmers' prices when grain is needed to load vessels; there is no one to bid competitively for new business. If a U.S. offer is not considered competitive, the buyer is not able to turn to another U.S. seller but must seek his grain from another source.

Conclusion

U.S. agriculture has become efficient throug the interaction of those engaged in all its a pects. The agricultural function as it exists the United States is a system which h evolved in response to the needs of agricultu itself and the nation. Despite what its criti contend, it has been extremely efficient; t problems in agriculture during the past deca have tended to be philosophical rather th economic. They have become economic b cause of the turns taken in the philosophic struggle. The continued attacks on the s called middlemen have been part of the stru gle. To suggest the introduction of an outsi entity in marketing, such as government, is propose replacing a vital part of a highly co petitive system with a real middleman who c function only in an area where he has no co petition. This can result only in destroying t competitive balance within the system, wi an accompanying loss of the incentives, whi have, in turn, been responsible for the innov tions which have been made U.S. agricultu excel and become the envy of the world.

There is an important difference in the rowth of regional cooperatives from that of ɔcal cooperatives. In 1929, just as regional rain cooperatives had established themselves s permanent institutions and had begun to xpand significantly their share of marketings, ıey were absorbed into the Farmers National irain Corporation (FNGC). The FNGC pro-ided government financial support for re-ional cooperatives in grain marketing. In 938, the FNGC discontinued its operation, nd the regional cooperatives reestablished ıemselves with only a 6% market share. The ıare of marketings since World War II has ıcreased gradually, reaching 21%–25% by the ıte 1970s.

The development pattern of exports by U.S. rain cooperatives appears to be similar to that f local and regional cooperatives. The first ɹstained attempt at export marketing came 'ith the establishment of Producers Export 'ompany (PEC) in 1958. Reynolds describes ıe primary objective of PEC as "develop-ıental" and the data indicate a relatively ıinor cooperative share of export sales. When EC terminated operations in 1969, several ooperatives had established export opera-ons, drawing heavily on the experience ained through PEC. Since 1968, integration at ıe export level by regional and interregional ooperatives has led to a significant increase in ıe share of direct export marketings. By 977, cooperatives directly exported 11% of ıe U.S. grain exports. In addition to direct xport sales, U.S. cooperatives in 1977 sold ıdirectly, but put through their own port levators, 6% of U.S. exports, making ooperatives the seller or handler of over 17% f U.S. exports of grains.

'oreign Country Grain Cooperative ʌlarketings

. review of producer cooperative activities in ıe major grain-exporting countries since Vorld War II suggests that the expansion in hare of grain marketings is not restricted to ıe United States. The major non-United tates grain-exporting countries include Au-tralia, Argentina, Brazil, Canada, France, nd South Africa. The grain export systems of ustralia, Canada, and South Africa are ominated by sole-export-authority grain-mar-eting boards and, therefore, the role of ırmer cooperatives in these countries, although important, generally is limited to first- and second-handler functions. In Argentina, Brazil, and France, grain cooperatives fulfill important roles at the first- and second-handler level and are becoming increasingly prominent at the export level.

In Argentina, a grain cooperative growth pattern similar to that of the United States can be observed. The Argentine local grain cooperatives originated assembly of grain in the late 1800s and, by the late 1970s, handled 50% of the grain at the first-handler level (Braidot). During the 1920s, the local cooperatives integrated into regional grain cooperatives. They currently market approximately 25%–30% of all Argentine grain and oilseeds. Argentine regional cooperatives began exporting prior to their U.S. counterparts, but have received several setbacks due to government monopolization of the grain-exporting activities during 1946–59 and 1973–76. However, after each period of government intervention, these producer organizations recuperated. Cooperative export shares of over 17% in 1979 surpass the 16% attained in the pre-intervention year of 1973.

The major soybean-exporting cooperatives in Brazil had their origins in the late 1950s and have been exporting only since the mid-1970s. Sixty percent of Brazilian soybeans are assembled at the first-handler level by local cooperatives. Regional exporting cooperatives receive 60% of the export licenses, but directly export only a small (8% to 10%) but increasing volume (Knutson, Cook, Sporleder). Rapid integration by cooperatives into transportation, processing, export facilities, and export institutions occurred during the late 1970s, and suggests that Brazilian cooperatives intend to at least maintain, if not increase, their share in the world oilseed market in the future.

In France, local marketing cooperatives handle approximately 70% of grain produced (Knutson, Cook, Sporleder; Sharp). Regional cooperatives, separately and with joint ventures, are the largest exporters of grain in France.

Cooperatives also play a significant role in the major grain-importing countries. In Japan, the largest feed grain importer is Zen Noh, a large, multiproduct cooperative. Zen Noh dominates the feed-compounding industry with approximately 40% of the market share. In the Netherlands, two diversified supply cooperatives process over 60% of the feed

used. Like Zen Noh, the Dutch cooperatives are experienced international importers and have participated in international cooperative marketing arrangements. Cooperatives also dominate the feed-compounding industries in the Federal Republic of Germany and Belgium and are significantly large in Italy, Spain, and South Korea.

Examination of the aforementioned trends reveals that farmer cooperatives in the major market-oriented exporting and importing countries are taking a more active role in the export/import functions in the world trade of grains. The descriptive results presented raise several issues about the future structure of the international grain trade. We briefly address three issues. What environment existed that fostered the observed trends? What factors in this environment enhance or constrain the growth of market share of cooperatives? Will the factors enhancing export growth continue to outweigh factors that might constrain growth?

Environment Creating Change

In much of the literature reviewed, both U.S. and international, a persistent yet undefined theme emerges—the general business environment that creates change in cooperatives has switched from "action because of adversity" to "action because of opportunity." Particularly, in the development of United States, Argentine, and Brazilian marketing systems, cooperative entry into grain marketing is preceded by adversity experienced by producers in gaining access to profitable markets for their products. The trends in figure 1 suggest that United States cooperatives at all three marketing levels—local, regional, and export—experienced learning periods with little market share growth during their first ten or more years of existence. But, after this initial learning period, market expansion was rapid, and is characterized by most students of these phenomena as "growth because of adversity." In the later periods, increase in market share of cooperatives is more gradual and is identified as more a function of "opportunity in the market exploited by management." Development of cooperative grain marketing at the local and regional levels in the other major market-oriented exporting countries follows a similar adversity-market opportunity pattern (Braidot; Knutson, Cook, Sporleder). Our studies suggest, however, that entrance by farmer cooperatives into export markets was more a result of market opportunity exploitation than reaction to adversity, particularly in Argentina and the United States (Braidot, Reynolds).

Factors Influencing Trends

We hypothesize that several factors have had a positive association with the observed upward trend in cooperative export marketings: (*a*) Cooperatives in all major countries have well-established cooperative bank systems. (*b*) Cooperatives originate between 40% and 50% of all grains in the market-oriented exporting nations. (*c*) In all of these same nations, a well-organized network of regional cooperatives exists. (*d*) Cooperatives in the major exporting countries control a sufficient portion of marketing facilities to achieve scale economies in handling grain. (*e*) Except in Argentina, cooperatives control a substantial percentage of the export and import facility capacity. (*f*) Grain importers perceive the quality of grain traded by cooperatives to be higher than the product of non-cooperatives. (*g*) Cooperatives in major grain importing and exporting nations have been beneficiaries of various public policies.

We also hypothesize several factors that may constrain the growth of cooperative export marketings: (*a*) the imperfectly competitive structure of the world grain trade, (*b*) rivalry between cooperatives in many local and regional markets, (*c*) management incentive systems of some cooperatives that are not conducive to expanded exports, (*d*) decentralized decision-making systems that are not always sensitive to the requirements of international trade, and (*e*) the basis of policy making (i.e., member-user board of directors) is rooted in the productivity of land and not the marketing-demand aspect of international grain sales.

Do Constraints Outweigh Advantages?

Numerous, exogenous factors, such as the world economic and the world grain situation, invariably will influence the sign and slope of the export market share trend of cooperatives. Of the factors that can be controlled by

operatives, it is often argued that two are ost important—member-user commitment d risk management.

There is much rhetoric but limited empirical idence on the importance of member comitment in increasing market share of operatives. Commitment involves setting m trading relations between producers and eir cooperatives. The "maintenance clause" mmitted U.S. farmers to support their local operative, but after cooperatives were ell-established, the clause was discontinued. nutson, Cook, and Sporleder found several ıde arrangements between importing and porting cooperatives that had played an imrtant role, especially in the initial stages of ernational trade between cooperatives. Deite some scattered examples of commitent, Knutson concluded that in the postorld War II period, institutionalized local d regional cooperative commitment was innificant in explaining increases in market ares at any level.

We suggest that the second controllable fac-, risk management, is the paramount factor at will determine the future presence of operatives in the international grain trade. e hypothesize that farmer cooperative board director awareness of the complexity of risk inagement in the international grain trade d their willingness to meet the challenge by iploying management equal to the task will termine the future sign and slope of the exrt-market share curve. Preliminary evince suggests that the quality of grain operative management worldwide has inased in recent years (Braidot; Knutson, ok, Sporleder).

References

American Institute of Cooperation Yearbook, annual issues. Washington, D.C., 1926 to present.

Braidot, Nester Pedro. "La Comercializacion Cooperativa en Argentina, El Caso del Comencio de Granos." M.S. thesis, Universidad de la Plata, Argentina, 1976.

Cook, Michael L., Ronald D. Knutson, and Thomas L. Sporleder. "Multinational Cooperatives: Their Potential Role in the International Grain Marketing System." *Proceedings of 17th International Conference of Agricultural Economists*, Banff, Canada, Sep. 1979.

Gardner, Chastina. *Beginnings of Cooperative Grain Marketing*. Washington, D.C.: Federal Farm Board, 1932.

Knapp, Joseph G. *The Advance of American Cooperative Enterprise: 1920–1945*. Danville, Ill.: Interstate Printers and Publishers, 1973.

———. *The Rise of American Cooperative Enterprise: 1620–1920*. Danville, Ill.: Interstate Printers and Publishers, 1969.

Knutson, Ronald D., Michael L. Cook, and Thomas L. Sporleder. *Assessment of International Cooperative Coordination*. Texas Agricultural Market Research and Development Center, Texas A&M University, 1980.

Reynolds, Bruce J. *Producers Export Company: The Beginnings of Cooperative Grain Exporting*. Washington, D.C.: USDA ESCS Farmer Coop. Res. Rep. 15, 1980.

Sharp, Wayne. *Trends in French Agriculture*. Washington, D.C.: USDA FAS Spec. Rep., Oct. 1976.

U.S. Congress, Senate. *Cooperative Marketing*. Senate Document 95, 70th Cong., 1st sess., 1928.

U.S. Department of Agriculture. *Regional Grain Cooperative Reports*, annual issues. Washington, D.C., 1938 to present.

U.S. Federal Trade Commission. *The Grain Trade*, vol. 1. Washington, D.C., 1920.

Performance of International Grain Marketing Systems: Discussion

Kelly M. Harrison

I would characterize the three papers as follows: (*a*) The Martin paper is an attempt to formulate a methodology for an objective evaluation of the performance of the international grain marketing system. (*b*) The Bunker-Cook paper is an historical review of the role of U.S. cooperatives in the international grain marketing system. (*c*) The Halow paper is an emotional appeal to retain the international grain-marketing system as currently instituted.

Halow's paper is of little value to this audience of professional agricultural economists because of its polemical character. We have a proud tradition of providing objective economic analysis as an input to participants in the political process; a process which sorts out the social, political, and ideological preferences of interest groups in order to set the policy framework in which economic activities like grain marketing will be performed. As individual participants in that process, we might or might not find his comments of interest, but they are of little professional value. I, and most agricultural economists, would fully agree with Halow's point that middlemen perform an important economic function. They do so for an honorable reason—to earn a livelihood, and they are often unfairly used as whipping boys. The balance of Halow's paper, however, implies that if one accepts those premises, then he must conclude that the U.S. grain-marketing system as currently instituted should be retained without questioning whether the current mix of world conditions, international market structure, and national policy variables may be producing results which are seriously detrimental to U.S. national interests.

The Bunker-Cook paper is a useful description of the evolution of cooperative efforts to participate in international grain markets. I find little with which to quarrel except th implication that having farmers act as middl men is philosophically preferable to propri tary firms. Some might go a step further assert that having cooperatives perform th intermediary functions in the world grai marketing system would enhance its soci performance. That, of course, is not necessa ily true.

Martin has proposed an approach to th evaluation of performance of the internation grain-marketing system. The focus on obje tive criteria for evaluating performance is u gently needed, as evidenced by the Halo paper which unfortunately characterizes mo of the writing on this subject.

Martin observes that it is "mandatory th the structure of the system be defined a thoroughly understood in undertaking co parative analysis of performance." I wou add that behavioral characteristics of partic pants also should be understood. He co tinues, "given the increasing role of the publ sector and the multiobjective nature of publ policy, the definition of performance cann be restricted to a conceptual framework th includes only variables internal to the gra sector." I agree with both conclusions. B having said that, Martin proceeds to conce tualize an evaluation methodology witho doing either, perhaps because there still substantial disagreement on the structure a behavior of participants, including poli makers in the international grain-marketi system. If that is true, we as a profession mu get on with additional work to correct th deficiency.

It is my own belief that world grain pri levels have been policy determined rather th supply-demand determined for years—mai as a derivative of U.S. domestic farm polic Supply and demand forces, working primari through open U.S. grain markets, fix day-t day price levels within constraints imposed government policy. Since the United Stat

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ıs been a major, if not dominant, supplier in ternational markets, U.S. domestic price ›licy has set price levels and other exporters ıve operated in their own best interest within at environment. The net effect has been an igopolistic competitive structure with U.S. ice leadership and market sharing among her exporters. The United States then acts the residual supplier through its open ex-›rt-marketing system. This, of course, is an ʼersimplification of a very complex process.

As Martin observes, it has been fashionable compare the performance of one sub-part of e international grain-marketing system (e.g., e United States) to another (Canada). I ıestion, however, whether that is the highest iority need. Perhaps a more urgent need is to ʼaluate the performance of the entire system light of U.S. economic and policy objec-ʼes. One might use the four P's of business arketing to conceptualize an evaluation pro-dure on behalf of U.S. citizens: i.e., ice—does the marketing system maximize turns to resource inputs? Product—does the stem supply overseas customers with prod-:ts which fully satisfy their needs and wants? ıysical distribution—does the logistical ›mponent of the system function smoothly to liver desired products at minimum cost? omotion—is the system dynamic in its ad-stment to changing wants and needs to main-in demand for products which can be pro-ıced economically with committed re-urces?

One must decide, as Martin observes, on hose behalf the performance evaluation is ing made. In other words, whose values and preferences count? He has not gone far enough in clarifying that issue. Nor has he specified how national security, foreign policy, and other domestic policy objectives would be factored into the evaluation.

Finally, none of the three papers has addressed what has become an increasingly important public policy issue: Has U.S. price policy in the context of existing world market structure and behavior tended to produce an export price level considerably below the real social cost for supplying commodities? Or, to state the same proposition in another way: What is the real economic value per unit of commodities exported—considering shadow prices for U.S.-produced energy, water resources, environmental costs, agricultural research, agricultural credit, and export promotion? It seems this issue should be at the forefront of any effort to evaluate the performance of the grain-marketing system from the standpoint of exporting nations. Andrew Schmitz and others have argued that several importing nations are taking advantage of exporting nations by extracting an optimum or near-optimum import tariff. Preliminary empirical analyses have estimated that the opportunity costs to the United States could be several billion dollars per year.

In conclusion, I applaud the association for focusing attention on these crucial issues. I urge association members to push ahead quickly with objective research and analysis. It appears that public pressures will bring these issues to a climax in the next few years. Your input can be most helpful.

Performance of International Grain-Marketing Systems: Discussion

Alex F. McCalla

The organizers of this session, I assume, had in mind two objectives: first, to help us get an improved handle on how we as economists can better deal with policy issues relating to market performance; and second, to add to our store of knowledge about how international grain markets really work. With respect to the first objective, Martin's paper is a thoughtful beginning upon which I will comment in more detail later. Halow's paper offers little if any insight into how international intermediaries perform their vital role in international trade. The Bunker and Cook paper presents some descriptive material about the role of the cooperative. But somehow, I expected more from this session. Major policy issues are bubbling with respect to grain marketing. Included among those are questions of whether the U.S. farmer is disadvantaged or helped by a private exporting system in a world of state traders and pervasive governmental policy intervention. Would an exporter association (a cartel) be a better road to take? Is unlimited expansion of grain exports in our long-run national interest? What are the implications of the changing structure of world grain markets for U.S. agriculture? Unfortunately, the papers presented this morning will not help policy makers much in wrestling with these and like issues. Nor do they help the profession much in improving our ability to do policy analysis.

Having made these general comments let me comment briefly on each paper.

Larry Martin's paper is a thoughtful piece. He makes the point that marketing systems exist in an environment of public policy. In particular, both the Canadian and U.S. marketing systems are to varying degrees shaped by public policy—a point Halow has yet to discover. Martin then proposes steps by which we could go about developing a set of performance indicators and measurable criteria. Most of his paper is devoted to this task an table 1 is a concise summary of thes thoughts. His scheme involves nine objectives, sixteen indicators, and forty-two quantifiable measures. He recognizes some difficu ties but does not really tell us how to solv them.

I would raise six questions about Martin' approach. (*a*) Do the objectives capture th scope of the interest of major participants? I general his objectives seem reasonable. (*b*) D the indicators accurately reflect those objectives? I have some doubts here as to wheth there is a one-to-one correspondence. (*c*) D the quantifiable measures allow us to reac conclusions about the indicators? I have som real doubts here. For example, twenty-thre of the forty-two measures are trends and var ations around trend. How are we to interpr these measures? (*d*) Can the measures b measured? Martin himself admits that there a trade-off between data available and th really needed. (*e*) What weights should be a tached to each objective? (*f*) How would on go about reaching an aggregate measure performance?

Unfortunately on the last three, Martin paper comes up short. What we have is major problem of multiattribute decision mak ing with highly interdependent variables. Ma tin has given us a good start, but there is a lon way to go.

Commenting on Halow's paper is mor difficult because there is little of intellectu substance in it. I had hoped we might lear about the role of the grain trade in intern tional markets. Instead we received a polem cal railing against some undefined enemy th is forcing us to socialism. Four pages are de voted to saying he does not like the term mid dlemen (all right, call them intermediaries be tween original producers and final consum ers). Three pages say profits are good. Tw pages say governments are bad and are in fa middlemen. He concludes by saying that w

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[m]ust not talk about the system because if we [d]o we will destroy its perfection. After reading [th]e paper, I assume that Halow must also have [ta]ken Logic I in college. His logic seems to run [a]s follows: middlemen are bad; governments [a]re bad; therefore, governments are middle[m]en. I think it is not worth saying any more. [H]alow did not address his subject but instead [g]ave us his philosophical position which I [s]uppose is all right, but it does not help much [in] objective analysis.

I have little to say about the Bunker and [C]ook paper. It is largely descriptive and I suppose is acceptable as far as it goes. Only toward the end of the paper do they raise analytical questions but then give us no analysis or judgment as to what the answers might be. We do not learn whether cooperative sales are FOB or c.i.f. We do not learn whether cooperatives are engaged in international risk bearing. No indication is given about how cooperatives deal with the crucial issue of information. These are only examples of what I would have expected. Hopefully they plan to go further.

Performance of International Grain-Marketing Systems: Discussion

Mark D. Newman

In discussing these three papers, it is useful to recognize that while Martin considers performance of the international grain-marketing system, Halow, and Bunker and Cook consider performance of individuals or groups of participants within the system.

I will consider the differences in the questions being addressed, some related issues which were not addressed, and implications for further research.

Martin's nine explicit criteria embody the traditional economic performance goals of efficiency, equity, and responsiveness. His framework emphasizes the multiplicity of participant interests and objectives that characterize the international grain-marketing system. The other two papers take narrower views of performance, leaving system performance questions to Adam Smith's invisible hand and concentrating on the interests of specific participants. Halow puts increasing exports as a system goal and profit as an individual participant goal. Bunker and Cook look at an increased cooperative export share as a performance criterion. Slope and trend become their performance measures.

As agricultural economists move ahead in research in this area, we need to consider performance criteria applicable to both the system and individual participants. We also need to consider the impact of the answer to the question of who will control U.S. agricultural exports and the international grain and oilseed trade. Martin's approach has potential to help answer this question. However, given the emphasis on Martin's paper by the other discussants, some comments on the points made in the other papers are in order.

Halow charges that "almost all those who attempt to crash into the grain-exporting field know relatively little about it other than that it looks like a good business." Halow's point is well taken. Some who have attempted to ent the international grain trade, and many wh purport to analyze it, fail to examine the m croeconomic foundations, the functional r quirements for export marketing, and th costs and risks involved. As Caves and m work (Newman 1980) have pointed out, thes are important considerations influencing i dustry structure, behavior, and performanc

We teach our students that certain domest marketing functions must be performed to gi time, form, and place utility to agricultur commodities, regardless of who perforn them. In export marketing, there are diffe ences in both the functional requirements a the participants involved. As agricultur economists, we need to respond to the r quirements and the participants. We (Ne man and Riley 1980) have presented o view of the microfoundations of export ma keting using nine functional components of t export process.

Moving on to the final paper, Bunker a Cook provide an interesting historical descri tion of the rise of cooperative expor although their data sources for exports U.S. grain cooperatives could be bett documented. They assert that cooperati marketing activity has shifted from "acti driven by adversity to action driven by oppo tunity." Regardless of the validity of t point, they fail to establish its relevance f the topic of this session.

The emphasis Bunker and Cook place predicting the sign and magnitude of the tre in cooperative exports provides an interesti speculative question. However, I should ha liked to have seen more emphasis on analy cal and prescriptive issues, i.e., shou cooperatives increase exports? Why? If s how?

A number of observers have asserted th cooperatives should increase exports. (what basis? The current session is supposed be considering performance. Are we talki

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bout higher producer returns, keeping the ›rivate trade "honest," or seeking a larger ıarket share per se? For farmer cooperatives, iven their particular characteristics as armer-controlled marketing organizations, here is a need to consider both price-related nd nonprice-related performance factors. 'hat requires evaluating the role and marketng objectives of cooperatives, which probably iffer from performance objectives for the verall system, and the potential contribution f exports to those cooperative objectives.

In other words, attempting to predict the ate and direction of change in cooperative xport market shares, as well as failing to tell he whole story, does not even ask enough uestions. For example, is the cooperative ble to better serve its members by increasing xports, especially on a direct or c.i.f. basis?

Cooperatives are currently in a period of ubstantial disagreement over the "proper" pproach to cooperative export marketing. eaders of some major cooperatives maintain hat emphasis should be placed on the "cooperative" in cooperative exports. They mphasize the importance of using people who ave "grown up" in cooperative organizations nd of building export marketing programs om the ground up. Other cooperative leaders mphasize the need to hire export experts, specially those who have worked in the priate trade. Some cooperatives have gone so ır as to purchase a share of concerns already ıvolved in the grain trade. The outcome of :tions of both of these groups will influence oth the role of cooperatives and who ultiıately controls U.S. agricultural exports. But unker and Cook did not consider such isıes.

In conclusion, let me add that Martin's aper gives us a tangible framework in which view performance of the overall internaonal marketing system from the perspectives f different participants. That he came up with uantifiable proxies for performance criteria hould not excuse researchers from seeking to nprove upon them, and to improve their unerstanding of the export marketing process.

The question of who will control export ıarketing of U.S. agricultural products must e continually explored. A number of recent events are worth noting: the entry of Phillip Brothers into grain marketing, the purchase of part of A. C. Toepfer by cooperatives to form InTrade, agreement by the U.S. government to serve as supplier of last resort in sales to Mexico, the rise of Farmers Export to fifth-largest U.S. exporter. All of these developments indicate that serious consideration is being given to the issue of control by those involved in the international grain-marketing system. But, where are the agricultural economists in the midst of this fray? Too often we have been content to substitute assertions for analyses, suggesting that cooperatives must increase their direct export shares, that farmers should stick to farming, or we have attempted to certify markets as perfectly competitive on the basis of application of statistical techniques to limited evidence.

The international grain-marketing process is both complex and risky. As researchers we need to look more deeply at both overall system performance and the functional foundations of the export process. While participants in the grain trade have been quite willing to proclaim that they serve the "public interest" through competition, they have not come forth with data that would permit analysts to support their case. Halow points out that good merchandisers must be able to sell grain at a lower price than they have bought it for, and still make a profit—which should demonstrate that economic analysts need to look more closely at such factors as size and scale economies, cross-subsidization, and risk management in order to understand what is going on.

References

Caves, Richard E. "Organization, Scale and Performance of the Grain Trade." *Food Research Institute Studies* 16(1977–78):107–23.

Newman, Mark D. "An Evaluation of the Economic Potential for Coordination of Export Marketing by U.S. Farmer Cooperatives." Ph.D. thesis, Michigan State University, 1980.

Newman, Mark D., and Harold M. Riley. *Coordinated Export Marketing by U.S. Farmer Cooperatives: Functional Aspects.* Washington, D.C.: USDA Farmer Coop. Res. Rep., forthcoming.

Critical Choices Affecting Agriculture in an Inflationary Economy
(R. J. Hildreth, Farm Foundation, Presiding)

Inflation, Portfolio Choice, and the Prices o Land and Corporate Stock

Martin Feldstein

During the rapid inflation of the past decade, the price of land has not only kept its real value but has increased far more rapidly than the general price level. (For the 1970s as a whole, the Agriculture Department's index of the price of farm land rose at an annual rate of 13%, nearly double the 7.4% annual rise in the general consumer price index.) While elementary economic theory would predict that land and all other real assets would hold their real value when the price level rose, the increase in the relative price of land caught economists as well as others by surprise.

The reasons for the rise in the relative price of land are multiple and complex. They range from the rise in the world price of food to the political instability in the Middle East and the fears of political change in Western Europe. No single paper, let alone a short theoretical one, could hope to provide a full explanation.

There is, however, a fundamental link between general price inflation and the relative price of land that deserves particular attention. This relation is the opposite side of the same coin that causes inflation to depress the price of common stock. In essence, inflation and the tax laws interact to raise the return on land and lower the return on reproducible capital.[1] The prices of these assets must then adjust to the new inflation expectation to make investors willing to hold both types of assets in the initially existing quantities. This requires the price of land to rise (relative to the general price level) and the price of reproducible cap tal to fall.

If uncertainty could be ignored, the pri changes would be such that the real after-t rates of return were equal both before a after any change in the rate of inflation. model of asset demand that makes this simp arbitrage assumption and ignores uncertaint however, can be misleading. This paper pr sents an explicit model of portfolio demar and uses it to show how the rate of inflati and its variance affect the real prices of la and capital.

The present paper is thus an extension two earlier studies in which I presented mo els of how the interaction of inflation and t tax rules alter the real prices of land (Feldste 1979) and common stock (Feldstein 1980a,b Although these papers considered the role uncertainty in a rather ad hoc way, a form model of portfolio choice derived from utili maximization was lacking. The purpose of th paper is to remedy that deficiency.

A basic result of the earlier papers (as w as of the present analysis) is that changes the rate of inflation alter the relative price assets while at any constant inflation rate t equilibrium real asset prices remain u changed. Thus, an unanticipated jump in t expected rate of inflation causes an immedia jump in the level of the land price. After th initial jump, the price of land increases at t same rate as the general rate of inflation.

This interpretation implies that the contin ous increase in the price of land during t 1970s can best be thought of as a combinati of (*a*) many small changes in the equilibriu real price of land (as the expected rate of ge eral price inflation changed), and (*b*) a contin ing increase in the nominal price of land at t prevailing rate of inflation. Similarly, the fall

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This paper is part of the NBER study of capital formation.

[1] In this paper, I use the term reproducible capital to refer to business capital and ignore owner-occupied housing. In many ways, owner-occupied housing behaves like land in its response to inflation.

the real value of share prices combines a series of falls in the equilibrium real price of shares with continuous increases in their nominal price.

The first section of this paper presents the model of portfolio equilibrium, while the second section derives the means and variances of the asset yields. The price equations for land and reproducible capital are then developed in the third section. Next, I derive the comparative static results for changes in inflation and in the uncertainty of inflation, then conclude by discussing some of the implications of this work and possible directions for further research.

A Model of Portfolio Equilibrium

The economy that I shall describe consists of identical individuals who hold a short-term nominal asset ("bills"), land, and (reproducible) capital. The assumption of identical individuals ignores another important feature that belongs in a more complete model of portfolio choice: differences in tax rates among investors. The distinction between taxable individual investors and tax exempt institutions can be particularly important in understanding the effect of inflation on portfolio investment (Feldstein 1980a, b). The current price level and current inflation rate are known, but the rate of inflation in the future is unknown. For simplicity, it is easiest to think of the economy switching from one expected inflation rate to another—the idea of an expected time pattern of future inflation rates might be more realistic but would be more complex to analyze without adding any fundamentally new insights.

The aggregate stocks of both land and capital are assumed fixed. While this may be a realistic approximation for land—the effective stock of land can change through the loss of topsoil, forestation, etc.—it is clearly not an appropriate model for capital. If the market price of existing capital assets (Tobin's q value, the index of common stock prices per unit of real capital) falls below replacement cost, the size of the capital stock will fall while a market price of existing assets above their replacement cost will cause an increase in net investment. The anticipation of the future change in the size of the capital stock will change the expected future yields per unit of capital and labor. That in turn will influence the initial changes in the prices of these assets. While it would clearly be desirable to incorporate this effect into the analysis, the combination of dynamic price adjustments and explicit portfolio choice under uncertainty is a more complex problem than I can currently solve.[2] I have chosen to focus on the portfolio choice aspect, but I recognize the importance of extending the specification to incorporate the dynamic general equilibrium response.

Consider an individual i whose initial holdings of land, capital, and money are $\bar{L}_i$ units of land, $\bar{K}_i$ units of capital, and $\bar{B}_i$ dollars of treasury bills. These holdings reflect some previous set of expectations about asset yields and the associated covariance matrix. When the Hicksian "week" begins, there is a new set of expectations (possibly but not necessarily identical with the old ones). These expectations imply a set of equilibrium asset prices p_L and p_K relative to the numeraire; the purpose of this section is to derive equations for these equilibrium prices.

The individual's initial endowment is, thus, $\bar{B}_i + p_L\bar{L}_i + p_K\bar{K}_i$, and must be redivided among new holdings (B_i, L_i and K_i) according to the wealth constraint,

$$(1)\quad B_i + p_L L_i + p_K K_i = \bar{B}_i + \rho_L \bar{L}_i + p_K \bar{K}_i.$$

At the end of the "week," each unit of land is worth R_L, each unit of capital is worth R_K, and each unit of bills is worth R_B. Thus, $R_L - 1$ is the return per week per unit of land, $R_K - 1$ is the return on capital, and $R_B - 1$ is the rate of interest. All of these are to be regarded as real after-tax rates of return. The returns to land and capital are uncertain while the bill return is riskless. This reflects the assumption that the inflation rate for the current week is known even though the future inflation is uncertain. The individual's wealth at the end of the week is thus,

$$(2)\qquad W_i = R_L L_i + R_K K_i + R_B B_i.$$

If each individual has the same quadratic utility function, expected utility can be written as a linear combination of the mean and variance of W_i:

$$(3)\quad E[u(W_i)] = E(W_i) - 0.5\gamma \cdot \mathrm{var}(W_i),$$

where $\gamma > 0$ is a measure of risk aversion, and the 0.5 is introduced to simplify subsequent calculations.

[2] Poterba and Summers have extended the type of analysis presented in Feldstein (1979, 1980a,b) to include an explicit capital-stock-adjustment process with feedback onto the path of asset prices. They assume certainty and, therefore, that the yields of all assets are always equated, at least up to a constant.

Equation (2) implies that

$$(4)\qquad E(W_i) = \bar{R}_L L_i + \bar{R}_K K_i + R_B B_i,$$

where the bars over the $\bar{R}_L$ and $\bar{R}_K$ denote expected yields for the one-week holding period. By using equation (1), this may be rewritten as

$$(5)\quad E(W_i) = \bar{R}_L L_i + \bar{R}_K K_i + R_B[p_L(\bar{L}_i - L_i) + p_K(\bar{K}_i - K_i) + \bar{B}_i].$$

Equation (2) also implies that

$$(6)\quad \mathrm{var}(W_i) = \sigma_{LL} L_i^2 + \sigma_{KK} K_i^2 + 2\sigma_{LK} L_i K_i,$$

where σ_{LL} and σ_{KK} are the variances of the one-week holding-period returns and σ_{KL} is the covariance.

The household's optimum portfolio is found by maximizing the value of expected utility in equation (3) subject to the constraint of equation (1). Using equations (5) and (6), this implies the first-order conditions:

$$(7)\quad 0 = \bar{R}_L - R_B p_L - \gamma(\sigma_{LL} L_i + \sigma_{LK} K_i), \text{ and}$$

$$(8)\quad 0 = \bar{R}_K - R_B p_K - \gamma(\sigma_{KK} K_i + \sigma_{KL} L_i).$$

The pair of asset demand equations may therefore be written:

$$(9)\ \gamma \begin{bmatrix} \sigma_{LL} & \sigma_{LK} \\ \sigma_{KL} & \sigma_{KK} \end{bmatrix} \begin{bmatrix} L_i \\ K_i \end{bmatrix} = \begin{bmatrix} \bar{R}_L - R_B p_L \\ \bar{R}_K - R_B p_K \end{bmatrix}, \text{ or}$$

$$\begin{bmatrix} L_i \\ K_i \end{bmatrix} = \gamma^{-1} \begin{bmatrix} \sigma_{LL} & \sigma_{LK} \\ \sigma_{KL} & \sigma_{KK} \end{bmatrix}^{-1} \begin{bmatrix} \bar{R}_L - R_B p_L \\ \bar{R}_K - R_B p_K \end{bmatrix}.$$

Since all of the investors are identical, each demands the same L_i and K_i.[3] Summing L_i and K_i over all individuals gives the total demand which must equal the total asset supplies: $N\bar{L}$ and $N\bar{K}$. Because all individuals demand the same assets, $\bar{L}_i = \bar{L}_j$ for all i, j and the subscript can be ignored. Thus,

$$(10)\qquad \begin{bmatrix} \Sigma_i L_i \\ \Sigma_i K_i \end{bmatrix} = N\gamma^{-1} \begin{bmatrix} \sigma_{LL} & \sigma_{LK} \\ \sigma_{KL} & \sigma_{KK} \end{bmatrix}^{-1} \begin{bmatrix} \bar{R}_L - R_B p_L \\ \bar{R}_K - R_B p_K \end{bmatrix} = \begin{bmatrix} N\bar{L} \\ N\bar{K} \end{bmatrix}.$$

Equation (10) can thus be solved explicitly for the equilibrium asset prices as functions of the expected yields, the covariance matrix, and the initial asset quantities:

[3] I assume the conditions on the covariance matrix and yield vector are such that $0 \le L_i$ and $0 \le K_i$, and $p_L L_i + p_K K_i \le p_L \bar{L}_i + p_K \bar{K}_i + \bar{B}_i$. These conditions must surely be fulfilled in an economy of identical individuals.

$$(11)\quad \begin{bmatrix} p_L \\ p_K \end{bmatrix} = R_B^{-1} \left[\begin{matrix} \bar{R}_L \\ \bar{R}_K \end{matrix} - \gamma \begin{bmatrix} \sigma_{LL} & \sigma_{LK} \\ \sigma_{KL} & \sigma_{KK} \end{bmatrix} \begin{matrix} \bar{L} \\ \bar{K} \end{matrix} \right], \text{ or}$$

$$(12a)\quad p_L = R_B^{-1}[\bar{R}_L - \gamma(\sigma_{LL}\bar{L} + \sigma_{LK}\bar{K})], \text{ and}$$

$$(12b)\quad p_K = R_B^{-1}[\bar{R}_K - \gamma(\sigma_{KL}\bar{L} + \sigma_{KK}\bar{K})].$$

The Means and Variances of Asset Yields

I turn now to the derivation of the mean real net-of-tax returns on the three assets and the corresponding covariance matrix.

Consider first the real net rate of return on bills. If the nominal short-term rate is r, the personal tax rate is θ, and the actual current inflation rate is π, the real net-of-tax rate of return is

$$(13)\qquad R_B = (1 - \theta)r - \pi.$$

Because the tax is levied on the nominal return, the real net-of-tax returns will vary with the rate of inflation. Following Fisher, empirical studies have confirmed that the nominal interest rate changes approximately point for point with sustained changes in the rate of inflation (see, e.g., Yohe and Karnovsky and Feldstein and Summers 1978). In the current notation, $dr/d\pi = 1$ is a reasonable approximation. This implies that $dR_B/d\pi = -(1 - \theta) < 0$; an increase in the inflation rate reduces the real net return on bills. For a high enough inflation rate, the real return can be negative. This is a particularly important feature of our tax system because it suggests that the usual assumption of equal yields on all assets may be wrong and a poor approximation when there is substantial inflation.

The return on a unit of a land consists of an income return and a capital gain or loss. If the marginal physical product per unit of land (per week) is F_L, the net-of-tax marginal revenue product is $(1 - \theta)pF_L$. Increases in the price of land are taxable capital gains. The capital gains tax rate is less than the tax rate on ordinary income and the effective tax rate is further reduced because capital gains are taxed only when the property is sold. I shall use the letter c to denote the accrual-equivalent effective tax rate, i.e., the rate which levied on accruals would collect the same present value of taxes as the actual rate levied on realizations. If the increase in the price of land during the week is $\dot{p}_L$, the after-tax capital gain is $(1 - c)\dot{p}_L$.

The total nominal return per unit of land is, thus, $(1-\theta)pF_L + (1-c)\dot{p}_L$. Since a unit of land costs P_L, the nominal return per dollar invested in land is $(1-\theta)pF_L/p_L + (1-c)\dot{p}_L/p_L$. The real rate of return is the difference between this nominal rate of return and the rate of inflation, $(1-\theta)pF_L/p_L + (1-c)\dot{p}_L/p_L - \pi$. Finally, the real return per unit of land (R_L) is just the product of the real rate of return and the price per unit of land,

$$R_L = (1-\theta)pF_L + (1-c)\dot{p}_L - \pi p_L. \tag{14}$$

There are two types of uncertainty about this return, corresponding to the income and capital gain components of the price change. Because the current price level is known, the income uncertainty is caused by the uncertain marginal physical product of land. If ϕ_L is the mean marginal physical product of land and $\tilde{v}$ is the random component with zero mean and variance σ_{vv},

$$F_L = \phi_L + \tilde{v}. \tag{15}$$

In a stationary equilibrium the price of land will rise at the same rate as the general price level: $\dot{p}_L/p_L = \pi$. Change in the expected future rate of inflation or in the expected future value of any other factor that influences the value of land will cause the price of land to change by more or less than the current rate of inflation. The uncertain change in the price of land can be written without restriction, as

$$\frac{\dot{p}_L}{p_L} = \pi + \tilde{\epsilon}, \tag{16}$$

where $\tilde{\epsilon}$ is a random variable with zero mean, variance $\sigma_{\epsilon\epsilon}$, and covariance $\sigma_{v\epsilon}$ with the random disturbance to productivity.

Substituting (15) and (16) into (14) yields[4]

$$\begin{aligned} R_L &= (1-\theta)p(\phi_L + \tilde{v}) \\ &\quad + (1-c)(\pi + \tilde{\epsilon})p_L - \pi p_L \\ &= (1-\theta)p\phi_L + (1-\theta)p\tilde{v} \\ &\quad - c\pi p_L + (1-c)p_L\tilde{\epsilon}. \end{aligned} \tag{17}$$

The mean return per unit of land is thus

$$\bar{R}_L = (1-\theta)p\phi_L - c\pi p_L. \tag{18}$$

The variance of this return is

$$\begin{aligned} \sigma_{LL} &= (1-\theta)^2p^2\sigma_{vv} \\ &\quad + (1-c)^2p_L^2\sigma_{\epsilon\epsilon} + 2(1-\theta)(1-c)pp_L\sigma_{\epsilon v}. \end{aligned} \tag{19}$$

The return on reproducible capital also consists of an income return and a change in the price of the asset. Because the tax rules are based on nominal accounting definitions, a rise in the rate of inflation increases the effective tax rate on the real income from reproducible capital. (Recall that this analysis uses "reproducible capital" to refer to business capital and ignores owner-occupied real estate.) This is caused primarily by the required use of historic cost depreciation but also reflects the method of inventory accounting. (See Feldstein and Summers 1979, and Feldstein 1980b, for a discussion of how higher inflation increases the effective tax rate on the income of nonfinancial corporations and of their equity owners.) If the marginal physical product per unit of land is F_K, the net-of-tax marginal revenue product in the absence of inflation can be written $(1-\theta)pF_K$. This ignores the separate corporate income tax and the differential treatment of dividends and retained earnings. Recognizing these would complicate the analysis without changing anything fundamental. It is convenient to approximate the extra tax burden per unit of capital as proportional to the rate of inflation; the real return per unit of capital is thus depressed by $\lambda\pi p$ at current prices. The real net-of-tax income per unit of capital is thus $(1-\theta)pF_K - \lambda\pi p$. If the increase in the market price of capital[5] during the week is $\dot{p}_k$, the net-of-tax capital gain is $(1-c)\dot{p}_K$. The total nominal return per unit of capital is thus $(1-\theta)pF_K - \lambda\pi p + (1-c)\dot{p}_K$, and the corresponding real return per unit of capital is

$$\begin{aligned} R_K &= (1-\theta)pF_K - \lambda\pi p \\ &\quad + (1-c)\dot{p}_K - \pi p_K. \end{aligned} \tag{20}$$

The income uncertainty of the return on capital reflects the uncertain marginal product of capital and can be represented by

$$F_K = \phi_K + \tilde{v}, \tag{21}$$

where $\tilde{v}$ has mean zero and variance σ_{vv}. The uncertain change in the price of existing capital assets can be written,

$$\frac{\dot{p}_K}{p_K} = \pi + \tilde{\omega}, \tag{22}$$

where $\tilde{\omega}$ has variance $\sigma_{\omega\omega}$ and covariance with $\tilde{v}$ of $\sigma_{v\omega}$.

Substituting (21) and (22) into (20) yields

[4] This is the natural extension to an economy with uncertainty of the return on land derived in equation (1.5) of Feldstein (1979).

[5] This perhaps is best thought of as the market price of common stock, i.e., claims to the existing capital stock rather than new capital goods.

$$(23)\quad R_K = (1-\theta)p(\phi_K + \tilde{v}) - \lambda\pi p + (1-c)(\pi + \tilde{\omega})p_K - \pi p_K = (1-\theta)p\phi_K + (1-\theta)p\tilde{v} - \lambda\pi p - c\pi p_K + (1-c)p_K\tilde{\omega}.$$

The mean return per unit of capital is thus,

$$(24)\quad \bar{R}_K = (1-\theta)p\phi_K - \lambda\pi p - c\pi p_K.$$

The covariance between the returns on capital and land depend in general on the full covariance matrix of all four random effects:

$$(25)\quad \sigma_{KL} = E\{[(1-\theta)p\tilde{\nu} + (1-c)p_L\epsilon][(1-\theta)p\tilde{v} + (1-c)p_K\tilde{\omega}]\} = (1-\theta)^2p^2\sigma_{\nu v} + (1-\theta)(1-c)pp_K\sigma_{\nu\omega} + (1-c)(1-\theta)pp_L\sigma_{\epsilon v} + (1-c)^2p_Lp_K\sigma_{\omega\epsilon}.$$

The Price Equations

The means and covariance matrix of the returns on land and capital can be used with equation (12a, b) to obtain explicit price equations for land and capital. It is useful to begin by substituting the mean values R_B and $\bar{R}_L$ into equations (12) to obtain the price of land:

$$(26)\quad p_L = (1-\theta)p\phi_L - c\pi p_L - \gamma(\sigma_{LL}\bar{L} + \sigma_{LK}\bar{K})/(1-\theta)r - \pi$$

Collecting and rearranging terms yields

$$(27)\quad \frac{p_L}{p} = (1-\theta)\phi_L/(1-\theta)r - (1-c)\pi + \gamma p_L^{-1}(\sigma_{LL}\bar{L} + \sigma_{LK}\bar{K}).$$

There are several significant things to notice about this expression for the real price of land (p_L/p). In the absence of risk aversion ($\gamma = 0$) and inflation ($\pi = 0$), the real price of land is just the discounted value of the expected return per unit of land, i.e., $p_L/p = \phi_L/r$. If there is inflation but no risk aversion, the relationship is more complex; the perpetuity at ϕ_L is discounted by $r - [(1-c)/(1-\theta)]\pi$. Since $(1-c)/(1-\theta) > 1$, this "net discount rate" can easily become "negative." That is, as π rises $r - [(1-c)/(1-\theta)\pi]$ approaches zero and the implied relative price of land become indefinitely large. When $(1-\theta)r < (1-c)\pi$, the value of p_L/p "passes through" infinity and becomes negative. More generally, for many plausible tax parameters, the relative price of land is implausibly sensitive to changes in π.

These results show the importance of explicitly recognizing the role of uncertainty and risk aversion in determining p_L/p. Equation (27) shows that risk aversion can eliminate the anomalous results. With $\gamma(\sigma_{LL}\bar{L} + \sigma_{LK}\bar{K}) > 0$ in the denominator, relative asset prices are not nearly so sensitive to differences in the mean real net rates of return.

A more complete characterization of the real price of land is obtained if σ_{LL} and σ_{LK} are rewritten in terms of the underlying variances and covariances. The essential features of the analysis are preserved, but the analysis is simplified by assuming that the income disturbances ($\tilde{\nu}$ and $\tilde{v}$) are independent of each other and of the price disturbances ($\tilde{\epsilon}$ and $\tilde{\omega}$). Such an assumption would be reasonable if investors knew that the disturbances $\tilde{\nu}$ and $\tilde{v}$ are serially independent so that a disturbance in one period has no implications about future values of F_L and F_K. With this simplifying assumption, the relevant variances and covariances of section 2 become

$$(28)\quad \sigma_{LL} = (1-\theta)^2p^2\sigma_{\nu\nu} + (1-c)^2p_L^2\sigma_{\epsilon\epsilon},$$

$$(29)\quad \sigma_{KK} = (1-\theta)^2p^2\sigma_{vv} + (1-c)^2p_K^2\sigma_{\omega\omega},$$

and

$$(30)\quad \sigma_{LK} = (1-c)^2p_Lp_K\sigma_{\omega\epsilon}.$$

Substituting these values into equation (27) yields

$$(31)\quad \frac{p_L}{p} = (1-\theta)\phi_L\Big/\Big((1-\theta)r - (1-c)\pi + \gamma p_L^{-1}\{[(1-\theta)^2p^2\sigma_{\nu\nu} + (1-c)^2p_L^2\sigma_{\epsilon\epsilon}]\bar{L} + (1-c)^2p_Lp_K\sigma_{\omega\epsilon}\bar{K}\}\Big),\ \text{o}$$

$$(32)\quad \frac{p_L}{p} = (1-\theta)\phi_L\Big/\Big((1-\theta)r - (1-c)\pi + \gamma\{[(1-\theta)^2(p/p_L)^2\sigma_{\nu\nu} + (1-c)^2\sigma_{\epsilon\epsilon}]p_L\bar{L} + (1-c)^2\sigma_{\omega\epsilon}p_K\bar{K}\}$$

In this form, the real price of land is defined as a quadratic function of tax rates, rates of return, the expected inflation rate, and the total wealth in land and capital. If the income risk is ignored ($\sigma_{\nu\nu} = 0$), the real price of land assumes the simple form,

$$(33)\quad \frac{p_L}{p} = (1-\theta)\phi_L/[(1-\theta)r - (1-c)\pi + \gamma(1-c)^2(\sigma_{\epsilon\epsilon})p_L\bar{L} + \sigma_{\epsilon\omega}p_K\bar{K}].$$

This case is also substantively interesting because the price risk can generally be expected

to be large relative to the income risk and because uncertainty about the future inflation rate contributes to the price risk but not the income risk.

The analogous equation for the real market price of capital is

$$(34)\quad \frac{p_K}{p} = [(1-\theta)\phi_K - \lambda\pi]/[(1-\theta)r - (1-c)\pi + \gamma(1-c)^2(\sigma_{\omega\omega} p_K \bar{K} + \sigma_{\epsilon\omega} p_L \bar{L})].$$

Some Comparative Static Analyses

Equations (33) and (34) can be used to examine how the real prices of land and capital respond to changes in inflation, the uncertainty of future inflation, and other such factors. Since the stock of capital is assumed to remain constant, the results can of course only indicate the direction and not the magnitude of the change.

The derivative of p_L/p with respect to the expected inflation rate is easily shown to be

$$\frac{d(p_L/p)}{d\pi} = -\frac{(p_L/p)^2}{(1-\theta)\phi_L} \cdot \left[(1-\theta)\frac{dr}{d\pi} - (1-c) + \gamma(1-c)^2\sigma_{\epsilon\epsilon}\frac{dV_L}{d\pi} + \gamma(1-c)^2\sigma_{\epsilon\omega}\frac{dV_K}{d\pi}\right].$$

where $V_L = p_L\bar{L}$ and $V_K = p_K\bar{K}$. Note first that, in the absence of risk aversion, the effect of inflation on the real price of land is positive if $(dr/d\pi) < (1-c)/(1-\theta)$. Since $c < \theta$, this will clearly be satisfied whenever $dr/d\pi < 1$. During the increasing inflation of the 1960s and 1970s, the nominal interest rate rose by approximately the rise in the rate of inflation, causing the real net interest rate to fall by $(1-\theta)d\pi$. In contrast, the real return on land falls only because of the smaller rate of capital gains tax on the nominal appreciation in the value of the land. Because the extra tax on bills per dollar of capital would exceed the extra tax on land, the price of land rises in the absence of uncertainty in order to equalize the yields.

Introducing uncertainty leaves this conclusion unchanged but suggests that the magnitude of the effect may be reduced. If $d(p_L/p)/d\pi < 0$, $dV_L/d\pi < 0$ since $V_L = p_L\bar{L}$ and $\bar{L}$ is constant. This positive term offsets some of the magnitude of the pure tax and interest rate effect; the economic reason for this is that as p_L rises, the investor has relatively more wealth in this form, which in turn raises the risk premium that the investor requires to hold even more land or, equivalently, which reduces the demand for more land and therefore the real price of land.

If the primary reason for the covariance between the unanticipated changes in the prices of land and capital ($\sigma_{\epsilon\omega}$) are the unanticipated changes in inflation, the term $\sigma_{\epsilon\omega}dV_K/d\pi$ is also likely to be positive, further reducing $d(p_L/p)/d\pi$ but nevertheless leaving it positive. For example, $dp_L/d\pi > 0$ and $dp_K/d\pi < 0$ imply $\sigma_{\epsilon\omega} < 0$ and $dV_K/d\pi < 0$, and therefore that $\sigma_{\epsilon\omega}dV_K/d\pi > 0$. Similarly, $dp_L/d\pi > 0$ and $dp_K/d\pi > 0$ imply $\sigma_{\epsilon\omega} > 0$ and $dV_K/d\pi > 0$, and therefore again $\sigma_{\epsilon\omega}dV_{\epsilon\epsilon}/d\pi > 0$. The economic reason (in the relevant case in which $dp_K/d\pi < 0$) is that inflation reduces the value of the investors' reproducible capital and, because the return on capital is negatively correlated with the return on land, reduces the demand for land and therefore its price.

The effect of uncertainty is nevertheless to dampen the effect of inflation and not to reverse it. To see this, note that the opposite implies a contradiction. If $dp_L/d\pi < 0$, $\sigma_{\epsilon\epsilon}(dV_L/d\pi) < 0$, which implies an even larger positive value of $dp_L/d\pi$.

A similar analysis shows that a higher rate of inflation reduces the real value of capital,[6] and that the uncertainty and risk aversion again dampen the magnitude of the effect.

Consider now the effect of an increase in the uncertainty of the future inflation rate. This increases $\sigma_{\epsilon\epsilon}$, $\sigma_{\omega\omega}$, and $|\sigma_{\epsilon\omega}|$. The relative increase in each term depends on the extent to which uncertainty about inflation is the source of the uncertainty about asset prices. Two extremes will illustrate the possible results. If most of the variation in the real price of land reflects variation in anticipated inflation, while little of the variation in the price of capital reflects the inflation uncertainty, an increase in the inflation uncertainty will raise $\sigma_{\epsilon\epsilon}$ while leaving $\sigma_{\omega\omega}$ essentially unchanged. Moreover,

[6] This depends on the relative magnitudes of the historic cost depreciation effect and the real interest rate effect. For an analysis with realistic parameters, see Feldstein (1980b).

if inflation is not a major source of $\sigma_{\omega\omega}$, it is possible (although not necessary) that $\sigma_{\epsilon\omega} = 0$. Total differentiation of equation (33) with respect to p_L and $\sigma_{\epsilon\epsilon}$, with $\sigma_{\epsilon\omega} = 0$, implies that $dp_L/d\sigma_{\epsilon\epsilon} < 0$, i.e., an increase in inflation uncertainty unambiguously reduces p_L while leaving p_K unchanged.

In contrast, consider the case in which inflation uncertainty is equally important for $\sigma_{\epsilon\epsilon}$ and $\sigma_{\omega\omega}$, and $\sigma_{\epsilon\omega} < 0$. If an increase in inflation uncertainty raises $\sigma_{\epsilon\epsilon}$ and $\sigma_{\omega\omega}$ by equal amounts and leaves the correlation between ϵ and ω unchanged, equations (33) and (34) imply that an increase in inflation uncertainty reduces both p_L and p_K. Investors respond to the increased uncertainty by demanding less land and capital and more of the riskless nominal asset.

More generally, the response of relative asset prices to an increase in inflation uncertainty will depend on the relative extent to which $\sigma_{\epsilon\epsilon}$, $\sigma_{\omega\omega}$, and $\sigma_{\epsilon\omega}$ are changed. An increase in inflation uncertainty might cause the real price of land to rise if investors wish to substitute both land and bills for capital.

Conclusion

This paper has focused on the specific question of how changes in expected inflation and in its uncertainty affect the real prices of land and of reproducible capital. The analysis shows how an explicit portfolio-choice framework can be applied to derive asset price equations and how, in this framework, the interaction of taxes and increased inflation causes a rise in the real value of land and a fall in the real value of corporate equities.

Two more general points are worth noting. First, the analysis shows the inappropriateness of the common assumption that inflation is neutral, i.e., that it does not alter real magnitudes. When there are taxes on capital income, this is false and inflation can have substantial real effects.

Second, the traditional assumption that prices adjust until net-of-tax yields are equal may be misleading. In the examples shown here, the existence of a finite price for land depends on the uncertainty of the asset yields.

This paper has shown that an explicit utility maximization model of portfolio choice can be applied to analyzing the effects of changes in the rate of inflation. A natural next step is to embed this analysis in a more general dynamic framework in which changes in the price of capital change the supply of new capital goods and therefore the future path of the real marginal products of capital and land.

References

Auerbach, Alan. "Inflation and Taxes in a Growing Economy with Debt and Equity Finance," M. Feldstein et al., appendix. *J. Polit. Econ.* 86(Part 2, 1978): S68–70.

Feldstein, Martin. *The Effect of Inflation on the Prices of Land and Gold.* National Bureau of Economic Research Work. Pap. No. 296, Harvard University, 1979.

———. *Inflation and the Stock Market.* National Bureau of Economic Research Work. Pap. No. 276, Harvard University, 1980a.

———. *Inflation, Tax Rules and the Stock Market.* National Bureau of Economic Research Work. Pap. No. 403, Harvard University, 1980b.

Feldstein, Martin, and Lawrence Summers. "Is the Rate of Profit Falling?" *Brookings Papers on Economic Activity* 1(1977):211–28.

———. "Inflation and the Taxation of Capital Income in the Corporate Sector." *Nat. Tax J.* 32(1979):445–70.

Fisher, Irving. *The Theory of Interest.* New York: Macmillan Co., 1930.

Poterba, James. "Inflation, Income Taxes, and Owner Occupied Housing." Mimeographed. National Bureau of Economic Research, Harvard University, 1980.

Summers, Lawrence. "Capital Taxation in a General Equilibrium Perfect Foresight Growth Model." Mimeographed. National Bureau of Economic Research, Harvard University, 1980.

Yohe, William P., and Denis Karnovsky. "Interest Rates and Price Level Changes, 1952–1969." *Rev. Federal Reserve Bank of St. Louis*, pp. 18–38, Dec. 1969.

[I]nflation, Agricultural Output, and [P]roductivity

[D]. Gale Johnson

[W]hy should inflation have an adverse effect [u]pon agricultural output and productivity? [S]ince most economists accept the view that [i]nflation is bad and should be avoided—if [d]oing so does not cost too much—our knee-[je]rk reaction is that inflation has significant [a]dverse effects upon output and productivity.

True, inflation redistributes wealth and in[c]ome, as most of us who work for universities [a]nd, in addition, have annuities derived from [d]efined contributions realize. And when infla[ti]on rates reach some levels, the breakdown of [c]onfidence in money and financial institutions [c]an have serious economic, social, and politi[c]al consequences. But have the inflation rates [o]f 10% to 15% to which we have been sub[je]cted during the past year had significant re[s]ource and productivity effects in agriculture? [W]hen I started to write this paper I was not [s]ure how I would answer this question. Was I [m]ore sure when I finished? I leave it to you to [ju]dge.

The first issue that I address is what has [h]appened to productivity in the economy and [in] agriculture during the 1970s. In considering [w]hat may have happened to the growth of [p]roductivity in agriculture, we should con[si]der that change in the context of the national [p]icture.

The available data on changes in national productivity, whether as measured by total factor productivity or by labor productivity (average labor product) show clearly that national productivity growth has been significantly slower since 1973 than in the years before. What is much less clear is why the slowdown has occurred.

What do the data show? Table 1 gives data on total factor productivity for the private domestic economy and selected segments. There can be little doubt that productivity growth after 1973 was at a lower rate than in any other period since 1948. Table 2 provides similar data on labor productivity, and the general picture is the same as for total factor productivity.

There are those who argue that the productivity slowdown started before 1973. Tables 1 and 2 give some support for that view, though the pre-1973 slowdown seems to have been concentrated in areas other than manufacturing.

However, there is little doubt that the sharp break in productivity growth occurred from 1973 on. There are at least two important competitors for explaining the decline. One is that 1973 was the year that oil prices were increased substantially. Another is that it was in 1973 that we started on a roller coaster of inflation, deflation, and inflation again. Other factors could be the adverse effects of environmental regulations, the low rate of capital investment in the U.S. economy, and the decline in real support of research. After noting how little can be attributed to these factors, Griliches came to the following equivocal but not unreasonable conclusions:

> There remain three interrelated forces: the rise of energy prices, accelerating inflation, and errors in our measures produced by the inability of the existing statistical framework to cope adequately with such changes. To me they appear to be the most likely suspects in this case. The main source of this suspicion lies in the coincidence of timing and the fact that the productivity slowdown appears to be worldwide, and not just restricted to the United States. Hence, any explanation for it must be based on factors that are not unique to recent U.S. history. (pp. 12–13)

Table 3 shows quite clearly that the decline in productivity, as measured by labor productivity in manufacturing, has not been only an American phenomenon. Of eleven high income countries, all but one (Germany) had a decline in labor productivity in manufacturing in 1973–76 compared to 1970–73.

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Table 1. Total Factor Productivity Growth, United States, 1948–76

Period	Manufac-turing	Mining	Contract Construc-tion	Transpor-tation	Private Domest Econom
1948–53	2.9	4.1	2.6	1.8	3.4
1953–57	1.0	2.2	1.8	2.7	2.0
1957–60	1.1	0.6	4.2	2.3	2.1
1960–66	3.9	4.6	2.0	4.2	3.4
1966–69	0.9	1.7	−0.3	1.9	1.5
1969–73	2.7	−0.7	−5.0	2.3	1.8
1973–76	0.1	−4.6	1.8	0.3	0.7
1948–76	2.1	1.7	1.0	2.4	2.3

Source: Kendrick.

Agricultural Productivity

In recent years there has been concern that productivity growth has slowed in agriculture. The National Academy of Sciences expressed its concern on this issue in *Agriculture Production Efficiency*. That study concluded that while there was inadequate evidence to support the conclusion of declining agricultural productivity (through 1972 or 1973), there were some trends pointing in that direction.

Have the concerns noted in the Academy report materialized? Table 4 indicates that the answer seems to be in the negative. I say "seems to be" because the inadequacies of our data base make it difficult to be quite certain that the growth of agricultural productivity has remained unchanged in recent years compared to earlier periods. Stated briefly, our currently available total factor productivity measure for agriculture suffers from three significant defects: (*a*) a failure to measure most changes in the quality of inputs, especially labor and machinery; (*b*) the use of base periods for weighting inputs that are too far apart in time; and (*c*) the failure to adjust output measures for climate changes. Other problems or difficulties are detailed in an excellent report of a task force of the AAE/ Given these difficulties, one must be quite ci cumspect. If one accepts the data as they ar recognizing the qualifications, certain concl sions follow:

(*a*) The growth of total factor productivi in agriculture during the 1970s was at least a high as for the two decades 1950–70. Produ tivity growth was higher during the 1950s tha during the 1960s but the average for the tw decades was essentially the same as for tl 1970s.

(*b*) Agriculture has not suffered the si nificant decline in either total factor producti ity or labor productivity growth that has o curred in the nonfarm economy, either tl total or private, since the mid-1960s.

(*c*) There does not appear to have been ar significant decline in the rate of growth of a ricultural productivity after 1973, in contra to what occurred in the rest of the econom Thus, agriculture appears to have escape the sharp decline in productivity evident in tl nonfarm economy after 1973.

There is a rough independent measure growth of productivity in agriculture, name the change in output to input prices. This me sure suffers from whatever defects there ma

Table 2. Labor Productivity Growth, United States, 1948–80 (Percent Change per Year)

Period	Nonfarm Manufacturing	Nonfarm Nonmanufacturing	Nonfarm Economy	Private Busines Economy
1948–55	3.3	2.4	2.7	3.4
1955–65	2.9	2.4	2.6	3.1
1965–73	2.4	1.7	2.0	2.3
1973–77	1.5	0.6	0.9	1.0
1977–78	2.5	−0.3	0.6	0.4
1978–79	0.9	—	−1.1	−0.9
1979–80	0.1	—	−1.5	−1.2

Sources: Council of Economic Advisers and U.S. Bureau of Labor Statistics 1980.

Table 3. Growth Rates of Output per Manhour in Manufacturing in Different Countries (Percent per Year)

Country	1970–73	1973–76	Difference
United States	4.4	1.3	−3.1
Canada	5.0	1.1	−3.9
Japan	6.7	2.8	−3.9
Belgium	8.4	6.7	−1.7
Denmark	7.1	5.4	−1.7
France	5.7	4.7	−1.0
Germany	5.4	5.8	+0.4
Italy	7.6	2.9	−4.7
Netherlands	8.0	5.2	−2.8
Sweden	5.6	1.2	−4.4
United Kingdom	5.0	0.6	−4.4

Source: U.S. Bureau of Labor Statistics.

be in the price indexes used, but avoids some of the difficulties of measuring input quantities. It introduces, however, the difficulty of comparative resource returns in agriculture and the rest of the economy. It should be noted that change in the relative output-input prices in agriculture is not a measure of the absolute change in total factor productivity but of the change in relative factor productivity. If real resource returns in the economy were increasing at, say, 2% annually, and if the output-input price index for agriculture declined by 0.5% annually, the growth in agricultural productivity would be 2.5% annually.

The use of the measure assumes that the return to agricultural resources increases at the same rate as in the rest of the economy. If the returns to agricultural resources (labor, land, and capital) increase relative to the returns elsewhere in the economy, the decline in the output-input farm price index would underestimate the increase in agricultural productivity.

From 1960 to 1970 the adjusted parity ratio (1910–14 = 100) declined from 82 to 77, or by 6%. From 1970 to 1979, the decline was from 77 to 73, or by 5%. During each of these two decades, the returns to agricultural resources increased relative to similar resources in the rest of the economy. A rough indication of the improvement was the increase in the ratio of per capita disposable incomes of the farm population to the nonfarm population during the two decades.[1] During the two decades, the

Table 4. Factor Productivity Growth in Agriculture, United States, 1940–79 (Percent Change per Year)

1940–50	1.7
1950–60	2.4
1960–70	1.3
1970–79	2.1
1940–79	1.9
1950–79	1.9
1960–79	1.7

Source: U.S. Department of Agriculture.

increase in the ratio was from approximately 55% in 1960 to near equality in 1979, with the improvement in terms of points being approximately 20 during each of the two decades. It is true that much of the improvement in the relative incomes of the farm population has been the result of a more rapid increase of nonfarm than of farm income. But the farm production activities of the rural farm population adjusted and apparently adjusted very well to the labor force changes associated with the increased importance of nonfarm employment of members of farm families.

These rough comparisons are consistent with the view that agricultural productivity has been maintained at a relatively high growth rate for the past two decades. In addition, there seems to be no support for the view that productivity growth in agriculture was lower in the 1970s than in the 1960s.

Whatever factors may have been responsible for the slowdown in the growth of productivity after 1973 in the United States and other economies seem not to have had much effect upon agricultural productivity in the United States. Or if there had been some effects, the effects were not large enough to have been caught by our inadequate measures of productivity growth. We perhaps have more of a puzzle on our hands, because U.S. agriculture apparently has escaped unscathed from the dramatic economic events that have occurred since 1972, than would have existed if productivity growth in agriculture had slowed significantly.[2]

[1] This measure is a rough indication since no effort is made to determine the amount of resources per capita in agriculture and in the rest of the economy. Thus, it is possible that resources per capita increased much more in agriculture than in the rest of the economy, though I doubt if such a change could account for much of the improvement in relative incomes.

[2] At this meeting last year, Vernon Ruttan gave a paper with a similar title, "Inflation and Productivity." While there are a number of similarities in our presentations, Ruttan is significantly more pessimistic than I am concerning recent and future productivity growth in agriculture (p. 901).

In the longer run, there is likely to be some effect of national productivity growth upon agricultural productivity growth. While the current episode shows that this long-run potential has so far not had adverse effects upon our agriculture, it would not be safe to assume that the lack of effect can go on indefinitely. In any case, farm people realize the benefits of productivity growth primarily through the increasing value of human effort. Slow or nil productivity growth in the rest of the economy means slow or nil increases in real labor earnings and thus in the alternatives available for the use of the human capital of farm people.

Expected Adverse Effect of Inflation

Why should we expect that inflation would have an adverse impact upon agricultural productivity or output? There are three reasons why negative effects may exist. One is that the rate of inflation is not correctly anticipated. A second reason is that a change in the rate of inflation may have effects on the prices of some or most agricultural products relative to input prices. Finally, the policies and interventions by government in response to the inflation may have inhibited the appropriate responsiveness of the markets. Each of the reasons implies that inflation increases the degree of uncertainty confronting farmers—uncertainty about prices and availability of inputs since the government may impose price ceilings or force the rationing of credit or specific inputs.

The economy of the United States does not have many of the institutional relationships that permit it to exist moderately well with inflation. We still function with long-term bonds and mortgages with fixed interest rates. But there is an indication that the sharp and generally unexpected rate of inflation has led to the introduction of a number of modifications of debt instruments. These include variable rate mortgages, rollover mortgages, and the various certificates of deposits tied to short- and intermediate-term treasury security rates. I do not know if there have been variable rate or rollover farm mortgages written during the past year, but such a possibility must certainly be under consideration by some financial institutions.

Inflation and Resource Allocation

For a rate of inflation—say in the range of 5% to 20%—it is unlikely that the errors in resource allocation due to incorrect anticipations will have a significant impact upon the real output level or productivity. True, some, if not most, asset prices will need to be readjusted as the true rate of inflation is revealed, but actual resource misallocations will have been quite small, especially in the short run of one production period. I am not saying that the effect is nil; certainly one would not expect such a statement from the author of *Forward Prices for Agriculture*. But the uncertainty created by variable inflation rates is an addition to existing uncertainty rather than an entirely new phenomenon. Thus, we can hardly expect that the added effects of variable inflation upon uncertainty could be of sufficient magnitude to be picked up by our imperfect measures of output and productivity.

I know of but one study that may throw some light on the adverse productivity effect of very high rates of inflation. Unfortunately, the agricultural area involved was afflicted with civil disturbance as well as a high and apparently unexpected rate of inflation. Briefly, Dittrich and Myers obtained access to detailed farm management data collected by the Japanese for three villages in North China for various years from 1937–40. These data were used to fit production functions, which were then used to estimate the efficiency of resource allocation in the different villages and years. In one village data were available for three consecutive years. In 1937 it was estimated that the actual resource allocation compared to an *ex post* reallocation of resources resulted in an income loss of 1.4%. Between 1937 and 1938, farm prices increased by 21%; the income loss due to resource misallocations was 3.3%. Between 1938 and 1939, farm prices increased by 136%; the income loss from resource misallocations was 17.5%. The authors concluded: "The findings . . . suggest strongly that the peasants of these farm surveys—operating within a framework of traditional agriculture and private ownership of land—were able to allocate scarce resources fairly efficiently. This was true as long as economic conditions reflected by rising farm prices did not change very rapidly" (p. 895).

As a net debtor in terms of financial assets, farmers usually gain from an unexpected in-

crease in inflation rates. However, this benefit is through an increase in real wealth and has rather little effect on current output and productivity.

Farm Output Prices

The second reason for an adverse effect of inflation is that the fact of largely unanticipated increase in inflation may result in adverse changes in relative prices and thus reduce output. This effect may arise where the domestic prices of major farm products are significantly affected by international market conditions. This is the situation for many U.S. farmers. Unless the U.S. exchange rate falls, an increase in the rate of inflation in the United States relative to the weighted inflation rate in the export destinations will not result in an increase in the absolute price of U.S. farm products. While in the long run purchasing power parties are likely to be reflected in exchange rates, in the short run relative exchange rates can move quite independent of relative inflation rates. This has clearly been the case for the dollar exchange rate since last October and especially from January 1980. When real interest rates rose absolutely and became significantly real, the exchange values of the dollar increased significantly. Between January and April 1980, the value of the dollar increased 13% in terms of the Deutsche Mark, 12% in terms of the yen and 6% in terms of the pound. But, when interest rates fell in April and the U.S. inflation rate appeared to be on the way to stabilization or decline, the exchange rate for the dollar fell and by July has returned to approximately the levels of a year earlier. Consequently, during the period of high absolute and real interest rates from December 1979 through April 1980, farmers were faced with high capital costs and declining real product prices. Some product prices fell in absolute as well as real terms, though a partial source of the absolute declines for the grains and soybeans may have been the U.S. suspension of grain sales to the Soviet Union. But even if there had been no suspension of grain sales, the prices of grain and other export products would have been under pressure due to the strength of the dollar in response to the inflow of funds attracted by high short-term interest rates. Later, starting in April and May, there was an outflow of funds as U.S. short-term interest rates fell; the dollar lost value in the foreign exchange market, and the net effect was to provide some strengthening of the dollar prices of major export products compared to what they otherwise would have been. In the context of circumstances in 1979/80, high interest costs were not offset by farm prices of the major export product rising at approximately the same rate as prices generally; in fact, quite the contrary occurred. High relative U.S. interest rates put downward pressure on the domestic prices of many farm products for a period of several months. These were critical months because many planting decisions had to be made during the period.

Since the slowdown in the inflation rate has been associated with a recession-induced decline in demand for the farm products with positive income elasticities of demand, the potential positive domestic price effect of the decline in the U.S. exchange rate has been at least partially offset by domestic events. The U.S. market for feed grains and corn is sufficiently large that changes in the domestic market can affect international market prices.

It is probable that the consequences of varying and unanticipated changes in the rate of inflation have had some small negative effect upon agricultural output and productivity. But these effects have been too small to be reflected in our measures. Not all of the consequences of the inflation-dominated events of 1979 and 1980 will be felt in the short run; both farmers and financial institutions will almost certainly modify their behavior for some time to come.

Governmental Policies

I will not dwell on the third reason for an adverse effect of inflation upon output and productivity—namely, governmental policies instituted in response to political demands to "do something about inflation." The sharp increase in interest rates, and the probable severity of the 1980 recession, resulted from an unwillingness of the administration to take appropriate action to reduce inflation before late 1979. By then, circumstances demanded that drastic action be taken by the Federal Reserve System. The drastic action taken will have ramifications upon prices and output for all of 1980 and probably well into 1981. One can only hope that since we have received the shock, it will not be all for naught because of a

rapid shift from contraction to expansion in the money supply.

Slow Economic Growth

Far, far more disturbing than any of the effects of inflation upon productivity in agriculture is the slow rate of growth that has afflicted our economy for the past decade. Sooner or later, and probably sooner, the competitive position of U.S. agriculture in world markets will be eroded by the slow growth of our economy. Agriculture's strong position in world markets is the result of efficient and competitive markets for inputs and outputs. The dynamic nature of American agriculture is due to the characteristics of our farm operators, the investment in research, and the rapid translation of research results into useful inputs produced at competitive prices (Johnson). One important advantage of U.S. agriculture has been an efficient, low cost transportation system to move products from the farm to the city with reasonable dispatch, and remarkable responsiveness to the rapid growth of exports. But important components of the system, particularly the railroads, appear to be on a path to disintegration at worst and much higher costs at best. We seem to be paying the price for a regulatory atmosphere that has never had the capacity to look more than a year or so into the future or to understand that the sources of competition for rail transport have changed in a century. Agriculture has not been without fault in the disintegration of the rail system—it has long pressed for low rates in the forlorn hope that someone else would pay to keep the system in a state of good condition and repair.

Inflation and Value of Assets

Earlier, I noted that farmers, as net debtors, gained from unanticipated increases in the rate of inflation. I gave no emphasis to this gain, noting that it did not significantly affect resource allocation. This is not strictly correct, since wealth is a variable that affects a number of decisions, such as consumption-savings or the form of investment or the desirability and availability of credit.

There is a potential effect of inflation that I have not mentioned, namely, the effect of farm land being considered one of the few good inflation hedges. Farm land prices have increased in real terms for the last four decades and have done so almost every year. However, during the past twenty years there seems to have been little relationship between the rate of inflation or the change in the rate of inflation and the size of the increase in the real value of farmland.

The price behavior of farmland does not appear to differentiate it from other types of real estate. Housing prices appear to have behaved in approximately the same manner as agricultural land prices. The only possible difference is that farmland is a major production asset for agriculture and, except for mining and forestry, this is not the case for other types of production. Thus, to the degree that farmland has been an inflation hedge and part of its current price so reflects, the acquisition of land becomes more difficult for those who must acquire it by purchase. But except for the greater difficulty of acquisition, primarily because our credit system does not provide for 100% loans, the fact that farmland is an inflation hedge is a disadvantage only if it should cease to be such a hedge. At that time, the owners of land would suffer a capital loss.

The very large real capital gains in agriculture during the 1970s have perhaps been an important factor in the ability of farmers to adjust to and to overcome the unanticipated events of the decade. In terms of 1967 dollars, the value of farm proprietors' equities increased by \$110 billion, or almost 50% (Melichar and Waldheger, p. 34). The real value of liabilities increased by less than \$22 billion. While there have been numerous claims that farm operators who have acquired their farms since 1972 have suffered such severe financial problems that increased foreclosures were inevitable, data through 1979 show no increase in the percentage of farm real estate sales due to foreclosures (Melichar and Waldheger, p. 57). The situation in 1980 and 1981 may be different, given the sharp drop in farm income that is likely to occur in the second half of 1980.

One reason that farm financial troubles have not dominated the agricultural concerns in recent years has been that during the 1970s real interest rates paid on all farm mortgages have been significantly negative. During the 1970s, prices received by farmers increased at an annual compound rate of 9%; interest rates on outstanding mortgage debt averaged about

7%. And it was not until 1979 that short-term interest rates paid by farmers were significantly higher than the annual rate of increase of farm product prices.

Concluding Comments

The inflation experienced by the United States during the 1970s has not had a measurable impact upon agricultural production or productivity. This statement should not be assumed to mean that inflation has had no effect, but simply that our measures are not sufficiently refined to pick up what effects there may have been. The prices of major export products were erratically affected by the high rate of inflation in 1979/80, the monetary policies that resulted in high rates of interests and a short-run significant increase in the dollar exchange rate.

Some of the potential adverse effects of inflation on resource use may have been offset by the positive transfers received by agriculture as a result of land's role as an inflation hedge and the negative real rates of interest that have prevailed in most years since 1972. Since agriculture is a very capital-intensive sector of the economy, its output may have been favorably affected by a low real cost of obtaining and holding capital.

The most alarming aspect of the performance of the U.S. economy since 1973 has been the low rate of productivity growth and the modest or nil growth of real wages. American agriculture is highly dynamic and progressive, but much of that dynamism depends upon the way in which the rest of the economy functions. When the rest of the economy is sluggish and floundering, eventually agriculture must be affected adversely.

References

American Agricultural Economics Association Task Force on Measuring Agricultural Productivity. *Measurement of U.S. Agricultural Productivity: A Review of Current Statistics and Proposals for Change.* Washington, D.C.: U.S. Department of Agriculture Tech. Bull. No. 1614, 1980.

Council of Economic Advisers. *Annual Report, 1979,* p. 68. Washington, D.C., 1979.

Dittrich, Scott R., and Ramon H. Myers. "Resource Allocation in Traditional Agriculture: Republican China, 1937–40." *J. Polit. Econ.* 79(1971):887–96.

Griliches, Zvi. "Productivity: Background Notes." Unpublished paper. Mar. 1980.

Johnson, D. Gale. "World Agricultural and Trade Policies: Impact on U.S. Agriculture." *Contemporary Economic Problems,* ed. William Fellner, pp. 293–324. Washington, D.C.: American Enterprise Institute, 1979.

———. *Forward Prices for Agriculture.* Chicago: University of Chicago Press, 1947; reprinted New York: Arno Press, 1976.

Kendrick, John W. "Productivity Trends and the Recent Slowdown: Historical Perspective, Causal Factors, and Policy Options." *Contemporary Economic Problems,* ed. William Fellner, pp. 28–29. Washington, D.C.: American Enterprise Institute, 1979.

Melichar, Emanuel, and Martha Waldheger. *Agricultural Finance Databook.* Washington, D.C.: Board of Governors of Federal Reserve System, Annual Series, Outlook Conference Issue, Nov. 1979.

National Research Council, Committee on Agricultural Production Efficiency. *Agricultural Production Efficiency.* Washington, D.C.: National Academy of Sciences, 1975.

Ruttan, Vernon. "Inflation and Productivity." *Amer. J. Agr. Econ.* 61(1979):896–902.

U.S. Department of Agriculture. *Changes in Farm Production and Efficiency, 1978,* p. 71. Washington, D.C.: ESCS Statist. Bull. No. 628, 1979.

U.S. Department of Labor, Bureau of Labor Statistics. *International Comparisons of Productivity and Labor Cost Trends in Manufacturing.* Washington, D.C.: USDL 78-444, 12 May 1978.

———. *Productivity and Costs.* Washington, D.C.: USDL 80-343, 28 May 1980.

Inflation, Agricultural Output, and Productivity: Discussion

John E. Lee, Jr.

A year ago Vernon Ruttan stood before you and stated that productivity growth in agriculture had definitely slowed and that inflation was partly responsible. Today, D. Gale Johnson stood before you and said productivity growth in agriculture had not slowed—was in fact growing faster than in the 1960s—and that inflation has had no measurable impact. Clearly the issue is not resolved and further investigation is in order.

A general complaint about both the Ruttan and Johnson papers is that while they contain some very interesting and useful observations, neither offers a rigorous analytical explanation of the cause and effect relationships between inflation and productivity. Thus, the value of Johnson's ideas will be enhanced if they inspire other economists to trace analytically and systematically through what theory suggests the impact of inflation should be on output and productivity, and then test those theoretical constructs against the evidence available.

Johnson's paper as well as the one by Ruttan reflect two rather general problems for the profession. The first is that the data and measures needed to trace the relationships in question are indeed less than perfect. The other is that as a profession we have done so little rigorous research on the subject of either inflation impacts or productivity that we are not quite sure what the questions are, let alone how to answer them.

Johnson suggests several reasons for the slowdown of productivity growth in the general economy. No doubt these are all contributors. I would suggest a few others that I believe are equally important. The first is the widespread emergence of an "inflation psychology." This is a relatively new phenomenon for this country, but I submit that it has had a major and pervasive impact on how people behave with regard to their economic and financial affairs. People save less, borrow more, and shift investments from production processes to appreciable assets.

A second important factor has been the growth of productivity-depressing institutional constraints. Johnson mentions environmental regulations. These are perhaps the most visible. But the examples are much more numerous and arise from the abuse of private power as well as from public policies and programs. The costs associated with these constraints add nothing to output. But they make the process of doing things slow, frustrating, and expensive.

Productivity also may be affected by a technological maturing process. The history of inventions reveals that technological developments tend to come in bunches. One breakthrough leads to another and a synergistic interaction evolves. Then there is an exhaustion of these developments until there is another breakthrough. There is an S-curve kind of effect with an accelerating phase and a decelerating phase. In a large and complex technological society there are always many subordinate S-curves which aggregate up to the national technological situation. Each of these may be in a different stage. But there are aggregate variations over time related either to an explosive interaction of subordinate technological developments or to some major event. The pent-up technology from World War II led to an explosion of new developments and a growth in productivity through the 1950s. There was a similar impact from the space program of the 1960s.

No doubt higher energy costs have had their impacts. But one must be careful not to attribute too much to this source. First, theory tells us that a change in relative factor prices should lead to an adjustment in factor mix, but not necessarily to general inflation or a decline in productivity. In fact, we know that the many constraints and market imperfections do not let the adjustments take place perfectly, at

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least in the short run. And in the real world there may never be a long run—only an endless series of short runs.

The second point about energy as the villain is that the real price of imported oil rose only twice in the 1970s: 1974 and 1979.

If Dr. Johnson's observation is correct that the rate of productivity growth was high in the 1950s, dropped in the 1960s, and rose again in the 1970s, one could hypothesize a number of explanations. A starting point might be to examine where the farm sector is on its aggregate production function and developments that may have caused shifts or changes in that function. Another possible explanation of what happened in the 1960s has to do with the way land is handled in the productivity statistics. Land diverted under commodity programs is included in inputs. Diversion increased in the 1960s relative to the 1950s, thus reducing productivity as measured. Diversion then dropped sharply in the 1970s, thereby increasing the measured productivity. Had diverted land not been included in inputs, the opposite productivity pattern would have resulted, especially since diverted land likely was less productive than land actually used in production.

Johnson suggests as an alternative measure of productivity change, the change in ratio of output prices to input prices. I interpret this to mean that if productivity increases, output prices will decline relative to input prices and the ratio will decline. Decline in this ratio is added to the real rate of returns to resources in agriculture to obtain the total increase in productivity. The empirical measurement problems with this approach are obvious, as Johnson notes. The necessary assumptions are also quite demanding. The ratios of prices received to prices paid can change for a variety of reasons. Tweeten's work suggests that inflation generates a real price effect or a cost-price squeeze, lowering the ratio of prices received to prices paid by farmers. Thus, Johnson's measure would not appear to be useful in the context of attempting to measure the impact of inflation on productivity if the measure of productivity being used has already been distorted or biased by inflation!

It is suggested that we have a puzzle on our hands because U.S. agriculture apparently has escaped unscathed from the dramatic economic events that have occurred since 1972. Perhaps not. I believe it is logical and explainable that productivity in agriculture has been less adversely affected by events since 1972. Energy costs are a smaller part of total cost of production in agriculture than in many other sectors. Events since 1972 have expanded exports, thus increasing utilization of a fixed capacity (land base). Third, capital investment has continued high in agriculture, financed in part by increased debt financing, encouraged in turn by low real interest rates, tax incentives, liberal credit terms, and plentiful supplies of loan funds. Finally, agriculture is still primarily a sector of sole proprietorships (although legally some are incorporated) where operators and families do most of the work and use relatively little hired labor. Despite farmers' complaints about regulation, they are relatively unconstrained compared to nonfarm business, especially the corporate bureaucracies. I really believe this is a significant factor.

Johnson indicates that the United States does not have many of the institutional mechanisms that permit it to exist moderately well with inflation. He suggests that we still function with long-term bonds and mortgages with fixed interest rates. This is not true for the farm sector. Federal land banks which now supply most of the institutional credit secured by real estate, instituted variable-rate mortgages in 1970 and now most of their loans are on variable rates. Even for production credit many banks have, in effect, gone to variable interest rates. They did this by substantially shortening the length of loans, thus requiring more frequent refinancing at new interest rates. With much shorter term loans in their portfolios, banks have also been able to respond much faster this year to changes in directions as well as magnitudes of interest rates. After decades of depending on fixed-rate passbook savings as a source of funds, and lending at fixed rates, agricultural bankers made the transition rapidly and remarkably well to a new world of borrowing via money market certificates with high, and highly variable, interest rates and making production loans for terms shorter than the production season and at rates pegged to the prime rate!

Johnson's explanation of commodity price developments over the past year (i.e., inflation caused high real interest rates, which caused rising value of the dollar which caused declines in export demand) fits textbook theory but does not square with the facts as I observe them. I believe this approach attributes too much to the impact of exchange rates. If one

examines the data carefully, one discovers that we had phenomenally large supplies of grains, but these were offset by stronger than expected export demand. Between July and December of 1979, successive crop reports added 1.1 billion bushels of corn to production estimates. This was nearly three times as much as the 400 million bushels not shipped to the Soviet Union. In addition, we had record large wheat and soybean crops and supplies. But exports continued to strengthen. Weekly shipments of grain from U.S. ports were at record levels. In fact, exports were so strong that we not only seriously under-forecasted the value of export sales but, more impressive, grain prices stayed remarkably (and surprisingly) firm despite the loss of sales to the Soviets and record large supplies. Thus, while grain prices might have been stronger had the value of the dollar not strengthened, I believe it would be difficult empirically to support Johnson's statement that "high relative U.S. interest rates put downward pressure on the domestic prices of many farm products for a period of several months." He goes on to say "these were critical months since many planning decisions had to be made during the period." I believe farmers were as concerned about supply of funds as about interest rates. Moreover, when the plantings data were in there were no discernible effects of high interest rates and fund shortages on acreages planted.

I am sympathetic to Johnson's lament about the erratic and over-reactive public policies, especially monetary policies, for dealing with inflation and the damage this erratic behavior will do to patterns of investment and resource allocation—hence productivity.

I also strongly agree that the slow rate of growth in productivity in the general economy is a far more serious threat to the nation's well-being than the small effects inflation might have had on agricultural productivity. Problems created for the rest of the economy will inevitably have adverse spillover effects on agriculture.

The Johnson paper is stimulating. I believe his general conclusions about productivity to be essentially correct. Moreover, the linkage between inflation and agricultural productivity is of more than academic concern. That will become clearer in the future when the cropland base is fully utilized (no idle acres). In that case, if demand for farm products is increased and if inflation is a concern, productivity growth in agriculture will be the key to whether real prices of farm products will rise (thus redistributing income to farmers and landowners and exacerbating inflation) or fall (thus ameliorating inflation and redistributing income from the farm sector to the rest of the economy and to the rest of the world).

References

Gardner, Bruce, et al. *Measurement of U.S. Agricultural Productivity: A Review of Current Statistics and Proposals for Change*. Washington, D.C.: U.S. Department of Agriculture ESCS Tech. Bull. 1614, Feb. 1980.

Ruttan, Vernon W. "Inflation and Productivity." *Amer. J. Agr. Econ.* 61(1979):896–902.

Tweeten, Luther. "An Economic Investigation into Inflation Passthrough to the Farm Sector." Mimeographed. Dep. Agr. Econ., Oklahoma State University, 1980.

Tweeten, Luther, and Steve Griffin. *General Inflation and the Farming Economy*. Oklahoma State University Agr. Exp. Sta. Res. Bull. p-732, Mar. 1976.

nflation, Portfolio Choice, and the Prices of ,and and Corporate Stock: Discussion

ames P. Houck

he paper by Martin Feldstein presents a ovel approach to asset pricing over time. It eparts from the present value and discounted te-of-return models familiar to most agricul- ral economists. By introducing differential x rates, portfolio balance concepts, and un- ertainty, it highlights demand-side forces hich affect relative prices of land and other ssets in the presence of general price infla- on.

This paper is an excellent example of how a mple, but plausible, model can be used to uminate complex ideas and shed light on atters often befogged by fuzzy debate. It is so an excellent example of how even a sim- e model can become almost unmanageable alytically when uncertainty and covariance e introduced among variables. Feldstein es his mathematics to illustrate economic asoning and make it more explicit. It is to his edit that he did not let mathematics get the pper hand in his paper, but it was a close call, my judgment. In what follows, I will men- on a few rather technical points and then nclude with some general comments about e paper's approach and results.

In order to linearize the rate-of-return ex- essions for land, capital, and treasury bills, l price variables are expressed as rate-of- ange indexes based on previous-period val- s. Then, the various asset prices and the tput price level are expressed relative to a meraire and, later, relative to each other. In der to grasp fully the implications of the odel manipulations, it is important for the ader to understand clearly how the author fines his prices and their changes over time. few more words of explanation on this topic rely would not have been a mistake.

The expected-utility expression in equation) is a standard formula for readers ac- ainted with the literature in this field. It would be to Feldstein's advantage to clarify for others that the 0.5 coefficient is not simply an arbitrary value introduced to simplify cal- culations but a fundamental part of the analyt- ical equation when λ is defined as the risk- aversion measure (Freund, p. 255). It be- longs there.

In my opinion, the introduction of uncer- tainty as it affects rates of change in land and capital prices and their respective marginal products is not as explicit and clear as one might hope. It is a bit too formal as it stands. Some plausible and quasi-realistic examples of factors affecting the relevant variances and covariances would have been enlightening, helping the reader to bridge the gap between the real world and the abstract theory.

On a more general note, I believe that the author should have noted explicitly that the inflation rate (π) is fully exogenous to this analysis. Inflation, in this model, affects rela- tive prices of land and capital, but is not af- fected in return by changes in these prices. There is no feedback. To relax the implicit assumption that inflation falls on this model like rain probably would unleash a hopeless computational tangle, but at least the point should be made.

In a similar vein, the reader also should notice that, while expectations about the rate of inflation are subject to uncertain variation, the inflation rate itself is not a random vari- able. I have a feeling that stochastic fluctua- tion in this variable in the real world is likely to be relatively more important than random vari- ation in some other things, the marginal prod- ucts of aggregates of land and capital, for in- stance.

Feldstein mentions several times in the text that the analytical results which emerge are creatures of four sets of variances and covariances, a differential tax system, and the inflation rate. Land and capital are exactly the same on the supply side; they are fixed. Thus, "reproducible" capital (K) is not reproducible

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at all within the model's context. While relaxation of this constraint transcends Feldstein's current analytical capacity (and mine too), the reader must keep in mind that these theoretical results do not depend at all on the fact that land and any sort of capital are fundamentally different from each other.

Thinking about this point leads me to suggest a partial approach to the matter. Assume, plausibly I believe, that people wish to own land because it is "different." This yen, or yearning, may not be coldly rational, but it does exist and is not random. It is a desire to hold land for reasons beyond productive or speculative returns. One could add a term to reflect this component of land demand to the wealth expression in equation (2), making the land-wealth portion $[(R_L + y_i)\cdot L_i]$, where y_i is the noneconomic measure of "wealth" attributable to holding a unit of land. Expressions could be added to explain y_i either individually or collectively for the society-wide aggregate of the y_i's which would appear ultimately in equation (10).

The marginal productivities of land and capital depend not only upon the amounts used i production but also upon underlying produc tion functions. Consequently, the derivative of equations (33) and (34) with respect to ϕ and ϕ_K illustrate how relative prices adjust a technology changes in a non-neutral way Under Feldstein's assumptions about θ, c, an $dr/d\pi$, an increase in land productivity woul unambiguously increase relative land prices the increase dampened to the extent that risl aversion and uncertainty enter the analysis Considering historic productivity trends, thi relation also may add to the explanation of th recent real-world land price phenomenon.

Overall, this is a good paper. It adds usefu perspective to a controversial area of stud and debate in agricultural economics. But i would be a mistake to argue that the matter i now settled.

Reference

Freund, R. J. "An Introduction of Risk into a Risk Pro gramming Model." *Econometrica* 24(1956):253–63.

Impacts of Federal Tax Policies on Potential Growth in Size of Typical Farms

Charles W. Eginton

Federal fiscal-monetary policy may have contributed to growth in size and declining numbers of farms by encouraging substitution of capital for labor. This paper reports implications of taxation policies for typical farm firms. To what extent have concessionary tax policies such as interest payment write-offs, depreciation allowance, and investment tax credit encouraged growth in size of family farms? To answer this and other questions relating farm firm growth to consumption-savings rates and ownership patterns, a computer model was developed to simulate growth over a thirty-year horizon. Simulations for six typical commercial family farms provided data on rates of growth in discounted net worth and on changes in size, ownership patterns, and in realized taxation rates with and without selected federal income tax features.

Benefits and costs associated with land purchases in inflationary times are unevenly distributed. Farmers who are able to meet the initial cash flow or who already have survived deficit years are more able to afford purchases, thereby accelerating the trend toward fewer and larger farms. A solution to the eventual cash flow shortfall has been suggested by Melichar's finding that increases in land prices will be consistent with productivity increases. Both Tweeten (1980a) and Melichar emphasize the importance of capital gains in the farmer's balance sheet. Tweeten shows that the existence of capital gains as deferred earnings allows the cash flow balance to offset the inflation-induced high mortgage interest rates. He has further shown that preferential tax treatment on capital gains will cause a shift to and from alternative investments by high-income investors.

Tweeten demonstrates that national inflation defers returns and raises immediate costs of farmland, thereby contributing to cash flow problems. Melichar showed that the cash flow problem is exacerbated by land earnings increasing faster than inflation, transforming farmland into a "growth stock." The result is that inflation tends to favor growth of farming units with sufficient equity positions to weather cash flow squeezes. Federal income tax provisions influence cash flow and, depending on the tax bracket and concession, affect the growth rates of farms.

A deterministic simulation model was developed to analyze farm growth. The model is designed to use USDA "Typical Farm Data Series" for 1979. These estimates of typical farm sizes, farm enterprises, labor requirements, land prices, and machinery complements were provided by Fawcett. From this data base, the model simulates thirty years for a farm operation oriented toward growth. Net taxable farm income is calculated using a 4% return-to-equity estimate developed by Tweeten (1979), and an operator labor-management return calculated within the model. Federal taxes are deducted from taxable income along with the family's projected living expenses and mortgage payments. The resulting annual cash flows are then used for growth. To determine the effects of various tax policies, after-tax incomes can be calculated with and without the tax feature under study. This approach allows estimation of the impact of a specific tax policy and comparison of the relative impacts of different tax features.

Numerous studies have assessed the impact of farm-related public policy on the structure of agriculture. Impacts of national fiscal-monetary policies on farm structure are now commanding attention. This study extends the research to examine interaction between inflation and taxation as forces changing farm structure and composition. Is the ideal of an owner-operator and family providing most of the labor, management, and capital for an economic farming unit doomed? Tweeten reports (1979) a chief obstacle to the family farm

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ideal is obtaining sufficient capital in the face of cash flow problems created by inflation. To show that the family farm ideal is still viable, for those fortunate enough to have adequate initial net worth, a zero initial-year cash-flow position was determined for the economic unit farms of the study. The initial tenure position was determined from a cash flow equation.

The cash flow equation is

> income from land [.04 × (value of acres owned and mortgaged)] + operator and family labor returns [2,600 hours × (farm labor wage rate)] + operator management return [.07 × (cash receipts)] + returns to investments in machinery [equity in machinery × (value in use of machinery complement)].

The cash outflow equation is

> living expense [$12,600] + mortgage payments [mortgage payment per acre × (1-equity requirements) (acres owned)] + federal income and self-employment taxes.

For the zero-cash-flow starting position, the inflow and outflow equations are set equal and solved for the number of acres owned. The result shows the maximum number of acres to which the operator can obtain title, subject to equity and other constraints listed in the equations. Remaining acres in the economic unit are rented. Inflation has increased the value of an economic unit providing full-time labor for a farm family to the point where a full-time farmer must be a high wealth individual to survive in farming.

The initial values of the six economic units in 1979 ranged from 1–2 million dollars. By using rental strategies to control enough land to fully use available labor and maintain a 30% equity in machinery, the entry level farmers on these six units needed an average of $206,500 in initial net worth. This initial net worth invested in farming provided a labor-management return of $12,600 with a zero cash flow in the initial year. Holding real dollar consumption at this level for thirty years, the firm applies all additional income to growth. From this high risk position of maximum leverage, the farmer can rapidly become a high income earner due to returns to capital gains on equity. As farm incomes become larger, the values of tax concessions increase because of graduated income tax rates. The importance of these tax concessions is further enhanced by inflation. The high income needed to realize large benefits from interest payment write-offs was met by typical family-operated economic units considered. These family farms are sufficiently capital-intensive to realize sizable benefits from depreciation allowances and investment tax credits. All of these tax benefits require high income and/or wealth available for investment. Capitalization of these tax benefits into the prices of agricultural inputs has placed low income, entry-level farmers at a severe disadvantage. Expansion of farm size as depicted by the growth in typical farms shown herein means fewer farms, although changes in size and numbers are exaggerated because growth tends to be at maximum levels unconstrained by risk, high consumption levels, competition among buyers for land, and other such factors.

The results of three experiments on six farms are reported in tables 1–6. The zero initial-year cash flow, minimum equity part-ownership starting position is used as a benchmark for comparison. The growth patterns and rates are tabulated along with the effective federal income tax rates for the initial and final years of the simulation. The constant dollar value of the estate transferred after inheritance taxes is reported as a percentage of the initial net worth to measure capacity for continuation of the typical family farm from generation to generation. The three general experiments, or alternatives to the baseline, reported here relate to (*a*) initial tenure, (*b*) consumption pattern, and (*c*) tax policy.

Baseline Case

Six typical commercial farms were chosen from a USDA typical farm series (Fawcett and Thornton). Space limitations precluded reporting results for all twenty farms in this data series. The farms used in this report represented a cross-section of the agriculture sector and include most of the major crop and livestock products. Because the concept of the family farm is basic to this study, all of the farms chosen have annual labor requirements of approximately 2,600 hours. Simulations were computed for various inflation rates, but all of the simulations reported here assumed a 6% average rate of inflation over thirty years and a real rate of interest of 3%. All mortgages are constant-payment, thirty-year, 9% loans. Income is generated from returns to equity, labor, and management.

Because of the high net worth requirements, it is presumed that the baseline farmer begins operation of the economic unit at age 35. This

lows time to accumulate the machinery and ıpital required to operate an economic unit ;ing a rental-ownership strategy. This rela- vely late start has implications for the estate ansfer. It is assumed that the farmer survives s thirty-year growth horizon, but no more. ederal income tax provisions and tax rates ıdexed) for 1979 apply to the entire thirty ;ars. The farming operation is transferred to ıe next-generation heir at 1979 estate tax tes indexed to inflation. (Or, two heirs re- iving half as much each could marry two ;irs with like inheritance to form a farming ıit.) The question considered was: Can a owth-oriented farmer start a family member an initial position equal to or better than his vn initial position?

To compare real net worth for various years ıder an inflationary scenario, dollars are dis- ›unted back to the initial year (1979) in tables -6. The percentage of annual change also is re- ›rted as a ratio of constant dollar values. The sults for the baseline cases show the dis- ›unted real net worth for all the farms grow- g at 6.3%–6.8% rates. The Oklahoma farm able 1) and the Illinois farm (table 3) had the ghest growth rates and experienced the eatest increases in taxation. If estate taxes e indexed for inflation as in the baseline ıse, they do not appear to be confiscatory. ach of the baseline farmers was able to trans- r a larger equity, and hence capacity, to form 1979-type economic unit than he began with. f course, alternative assumptions concerning ımber of heirs change the results. As the rmer expands, higher income forces him to higher tax brackets. The current grad- ıted income tax has the effect of slowing ›wn the rate of growth even when indexed r inflation. This is shown by the consistently wer growth rates for the later years of the nulation.

ıitial Tenure Experiment

he baseline scenario featured a part-owner veraged to the furthest extent permitted by ısh flow. Different initial ownership positions fect growth rates for all farms studied. The ıtes of growth in discounted net worth appear be correlated with the degree of initial verage. The greatest rate of expansion in net orth is for an initial full renter. Both the full ›nters and the zero-cash-flow baseline farmers were able to gain ownership (though not necessarily with full equity) of an economic unit within the thirty-year growth horizon. The full renter consistently could remain in the lower tax brackets, while the full owner's growth was restricted by higher tax rates. The very high initial net worth of the full owner combined with high estate tax rates reduced the percentage of initial net worth transferred. The greater absolute increase in net worth and acres for the full owner supports the widely held view that the established owner-operator is in a position to outbid competitors for land.

Alternative Consumption Experiment

In this experiment the baseline case of constant minimum consumption levels regardless of income was modified to allow consumption to increase with income. The consumption function used specified 70% of the cash flow surplus for additional family spending beyond the $12,600 minimum level. The increased consumption reduced investment rates and annual cash flows thus limiting the farmer's ability to service additional mortgages. This change had a greater effect on firm growth than any other changes from the baseline case. In four of the six farms, increased consumption levels prevented growth beyond the initial family size. Additional consumption reduced the number of acres mortgaged in the thirtieth year of the simulation of the Minnesota farm (table 2) from 348 to 62. The dampening of growth would have been more pronounced with higher consumption had not lower federal taxes attended the high-consumption scenario. Because of space limitations, only selected results are presented here, but other data show large combined effects of consumption and tax policies on growth.

Alternative Tax Policy Experiment

Four tax policy alternatives illustrate the importance of various tax concessions to farm growth. The baseline situation was simulated with all available tax advantages in 1979 (selected alternatives such as cash accounting and income averaging were omitted because they would have little impact in the deterministic simulation used herein) and then rerun with one tax advantage eliminated. The

Table 1. Results of Thirty-Year Growth Simulation Beginning with a Typical Oklahoma Commercial Cotton, Wheat, Beef Farm in 1979

		Acres			Discounted Real Net Worth		Federal Income Tax Rate (%)	Estate Transfer as % of Initial Net Worth
		Owned	Mortgaged	Operated	Total (1979/$)	% Annual Change		
Baseline								
	Year 1	111	258	960	164,799	8.4 (yr 1–15)	0.0	—
	Year 30	266	1,102	1,368	1,101,523	5.3 (yr 15–30)	46.2	433.3
	Change	155	844	408	836,724	6.8 (yr 1–30)	46.2	—
Initial tenure								
	Year 1	960	0	960	1,205,964	4.4 (yr 1–15)	28.4	—
Full owner	Year 30	1,313	2,526	2,613	3,424,375	3.0 (yr 15–30)	290.7	130.0
	Change	353	2,526	1,653	2,218,411	3.7 (yr 1–30)	262.3	—
	Year 1	0	0	960	57,439	12.6 (yr 1–15)	1.2	—
Full renter	Year 30	152	927	1,080	783,945	6.6 (yr 15–30)	19.5	909.5
	Change	152	927	120	726,506	9.5 (yr 1–30)	18.3	—
With consumption function								
	Year 1	111	258	960	164,799	6.3 (yr 1–15)	0.0	—
	Year 30	194	574	960	671,800	3.8 (yr 15–30)	42.2	274.5
	Change	83	316	0	507,001	5.0 (yr 1–30)	42.2	—
Alternative tax policies								
	Year 1	111	258	960	164,799	8.3 (yr 1–15)	0.0	—
Nonindexed taxes	Year 30	222	907	1,129	987,120	4.6 (yr 15–30)	145.0	269.6
	Change	111	649	169	822,321	6.4 (yr 1–30)	145.0	—
	Year 1	111	258	960	164,799	6.7 (yr 1–15)	0.0	—
No interest write-off	Year 30	194	694	960	747,136	4.3 (yr 15–30)	120.0	303.3
	Change	83	436	0	582,338	5.5 (yr 1–30)	120.0	—
	Year 1	111	258	960	164,799	7.7 (yr 1–15)	0.0	—
No depreciation allowance	Year 30	227	1,021	1,249	962,089	5.0 (yr 15–30)	61.9	386.6
	Change	116	763	289	807,579	6.3 (yr 1–30)	61.9	—
	Year 1	111	258	960	164,799	8.2 (yr 1–15)	0.0	—
No investment tax credit	Year 30	251	1,077	1,329	1,057,619	5.2 (yr 15–30)	49.4	417.6
	Change	140	819	369	892,820	6.6 (yr 1–30)	49.4	—

Table 2. Results of Thirty-Year Growth Simulation Beginning with a Typical Minnesota Commercial Corn and Beef Feeding Farm in 1979

		Acres			Discounted Real Net Worth		Federal Income Tax Rate (%)	Estate Transfer as % of Initial Net Worth
		Owned	Mortgaged	Operated	Total (1979/$)	% Annual Change		
Baseline								
	Year 1	57	131	320	182,570	8.0 (yr 1–15)	0.0	—
	Year 30	148	479	628	1,080,808	4.8 (yr 15–30)	40.9	384.4
	Change	91	348	308	898,238	6.3 (yr 1–30)	40.9	—
Initial tenure								
	Year 1	320	0	320	925,111	4.7 (yr 1–15)	23.8	—
Full owner	Year 30	470	970	1,440	2,756,876	3.0 (yr 15–30)	119.2	167.1
	Change	150	970	1,120	1,831,765	3.8 (yr 1–30)	95.4	—
	Year 1	0	0	320	68,892	11.7 (yr 1–15)	0.0	—
Full renter	Year 30	97	382	480	787,514	6.2 (yr 15–30)	20.1	761.5
	Change	97	382	160	718,622	8.8 (yr 1–30)	20.1	—
With consumption function								
	Year 1	57	131	320	182,570	6.0 (yr 1–15)	0.0	—
	Year 30	114	193	320	637,097	3.0 (yr 15–30)	49.5	235.8
	Change	57	62	0	454,527	4.4 (yr 1–30)	49.5	—
Alternative tax policies								
	Year 1	57	131	320	182,570	8.0 (yr 1–15)	0.0	—
Nonindexed taxes	Year 30	143	364	508	970,510	4.1 (yr 15–30)	145.3	348.5
	Change	86	233	188	787,940	6.0 (yr 1–30)	145.3	—
	Year 1	57	131	320	182,570	6.7 (yr 1–15)	0.0	—
No interest write-off	Year 30	120	307	428	822,830	4.2 (yr 15–30)	106.5	299.1
	Change	63	177	108	640,260	5.4 (yr 1–30)	106.5	—
	Year 1	57	131	320	182,570	7.3 (yr 1–15)	0.0	—
No depreciation allowance	Year 30	135	372	508	945,794	4.5 (yr 15–30)	85.9	340.3
	Change	78	241	188	763,224	5.9 (yr 1–30)	85.9	—
	Year 1	57	131	320	182,570	7.1 (yr 1–15)	0.0	—
No investment tax credit	Year 30	143	445	588	1,041,114	4.7 (yr 15–30)	53.3	371.6
	Change	86	314	268	858,544	6.2 (yr 1–30)	53.3	—

Table 3. Results of Thirty-Year Growth Simulation Beginning with a Typical Illinois Commercial Corn and Soybean Farm in 1979

		Acres			Discounted Real Net Worth		Federal Income Tax Rate (%)	Estate Transfer as % of Initial Net Worth
		Owned	Mortgaged	Operated	Total (1979/$)	% Annual Change		
Baseline								
	Year 1	42	97	400	214,544	8.4 (yr 1–15)	0.0	—
	Year 30	125	374	499	1,455,373	5.4 (yr 15–30)	51.5	428.2
	Change	83	277	99	1,240,829	6.8 (yr 1–30)	51.5	—
Initial tenure								
	Year 1	400	0	400	1,784,397	4.6 (yr 1–15)	35.2	—
Full owner	Year 30	561	1,198	1,760	5,569,546	3.5 (yr 15–30)	151.7	137.1
	Change	161	1,198	1,360	3,785,149	4.0 (yr 1–30)	116.5	—
	Year 1	0	0	400	61,589	14.0 (yr 1–15)	4.1	—
Full renter	Year 30	93	267	400	975,469	6.5 (yr 15–30)	30.0	1,037.9
	Change	93	267	0	913,880	10.1 (yr 1–30)	25.9	—
With consumption function								
	Year 1	42	97	400	214,544	6.5 (yr 1–15)	0.0	—
	Year 30	68	110	400	786,985	2.9 (yr 15–30)	99.8	244.4
	Change	26	13	0	572,441	4.6 (yr 1–30)	99.8	—
Alternative tax policies								
	Year 1	42	97	400	214,544	8.2 (yr 1–15)	0.0	—
Nonindexed taxes	Year 30	115	224	400	1,166,667	4.0 (yr 15–30)	187.8	350.8
	Change	73	127	0	952,123	6.0 (yr 1–30)	187.8	—
	Year 1	42	97	400	214,544	6.7 (yr 1–15)	0.0	—
No interest write-off	Year 30	94	206	400	955,001	4.3 (yr 15–30)	151.7	292.1
	Change	52	109	0	740,457	5.4 (yr 1–30)	151.7	—
	Year 1	42	97	400	214,544	7.8 (yr 1–15)	0.0	—
No depreciation allowance	Year 30	121	299	420	1,240,157	4.8 (yr 15–30)	80.2	371.0
	Change	79	202	20	1,025,613	6.3 (yr 1–30)	80.2	—
	Year 1	42	97	400	214,544	8.2 (yr 1–15)	0.0	—
No investment tax credit	Year 30	121	338	459	1,394,168	5.3 (yr 15–30)	66.2	412.0
	Change	79	241	59	1,179,624	6.7 (yr 1–30)	66.2	—

ffering value distribution between real and ɔnreal estate assets among the typical farms fluenced the sensitivities to changes in tax ɔlicies. Capital improvement-intensive farms ɪeanut, table 4 and hog, table 5) respond ore to depreciation and investment tax cred-ɜ, while land-oriented farms derive relatively ore benefits from interest payment write-ffs. Interest payment write-offs were shown be extremely important for all farmers with :pansion opportunities. The value of the tax ɪncessions is most easily seen by the effect ı the federal income tax rate paid in the final ɜar of the simulation. Using this measure, the rgest tax decrease would result from index-g income tax rates. The Washington farm able 6) shows a decrease from 194.8% to ɔ.3% effective income tax rate. Removing ɪy of the existing tax advantages would in-ease the effective tax rates for farmers. terest payment deductions appear to en-ɔurage expansion in acreage, while deprecia-ɔn and investment tax credit benefits en-ɔurage the substitution of purchased capital r other inputs.

ımmary

ntry-level family farmers failed without tax ɔncessions. Termination of favorable tax eatment would mean trauma to a financially eak owner who purchased farmland with ex-ɜctations of continuing tax benefits. Of the x experiments, interest payment write-offs ıd the greatest effect on rates of farm growth ɪ subsidizing leveraged purchases of land, us accelerating the trend toward fewer and rger farms. Upward adjustments in real farm ze necessary to realize a given labor-anagement return in the face of changing chnology and the growing opportunity cost farm labor are not considered in this report. igher growth rates permitted by utilization of deral income tax provisions increase com-ɜtition for farms, crowding out some existing rmers. The established full owner is in the est position to compete for land, but progres-ive tax rates appear to diminish this advan-ıge. An alternative worthy of research is lim-ations on tax concessions such as interest ayment write-off and depreciation allow-nces to set dollar amounts (as investment tax redits are now limited) to prevent continuing inflation from preferentially subsidizing super farms to grow even larger.

The depreciation tax benefit had less impact on the expansion of the land-dominated farms studied; however, the highly mechanized, capital-intensive farms grew at rapid rates due to the depreciation allowance. The net effect over the long run was to encourage the use of capital relative to labor, thus exacerbating the trend to increased size and reduced numbers of farms.

Investment tax credit concessions benefited all farms, with capital-intensive farms benefit-ing proportionally more than the land-intensive farms. Each farm in the study was able to increase its growth rate due to the combination of tax benefits presently avail-able. Growth rates were also found to be highly sensitive to savings rates. Indexed in-come tax rates were extremely beneficial to all farmers. In every case, the effective tax rate in the thirtieth year was decreased by at least 100% by indexing. With the 6% inflation rate results reported here, farmers were able to use the existing tax provisions effectively, thus reducing the severity of nonindexed income tax rates. With higher (currently existing) inflation rates, options to avert very high (maximum) tax rates are diminished.

Finally, implications of estate tax policies for intergenerational transfer of family farm firms were briefly considered. For the experi-ment, the initial ownership position was the most important determinant of value trans-ferred. Consumption patterns during the simu-lation also had a major impact on the relative size of estate and thus on after-tax transfer. Combined effects of high initial net worth and high inflation rates on estate taxes increase the value of indexing inheritance tax rates.

This study illustrates that substantial real capital gains can be expected for farmers oriented to expansion at the expense of cur-rent consumption. Each farm's operation be-gins with control (rent or ownership) of a typi-cal commercial farming unit, with growth measured by accumulation of owned land, first by purchasing formerly rented acres and then by expanding the size of operation beyond the initial family size. Growth is triggered and lim-ited by cash income. The impact that cash flow rather than equity is the limiting factor in firm growth is consistent with previous analysis emphasizing the contribution of inflation to the cash flow problem facing newly established and expanding farmers (Tweeten, 1980a).

Table 4. Results of Thirty-Year Growth Simulation Beginning with a Typical Iowa Commercial Corn, Soybean, Hog Farm in 1979

		Acres			Discounted Real Net Worth		Federal Income Tax Rate (%)	Estate Transfer as % of Initial Net Worth
		Owned	Mortgaged	Operated	Total (1979/$)	% Annual Change		
Baseline								
	Year 1	25	59	320	131,822	7.5 (yr 1–15)	0.0	—
	Year 30	94	190	320	763,568	5.1 (yr 15–30)	37.2	286.9
	Change	69	131	0	631,746	6.3 (yr 1–30)	37.2	—
Initial tenure								
Full owner	Year 1	320	0	320	1,269,064	3.8 (yr 1–15)	29.2	—
	Year 30	443	636	1,080	3,173,453	2.6 (yr 15–30)	95.4	140.7
	Change	123	636	760	1,904,389	3.2 (yr 1–30)	66.2	—
Full renter	Year 1	0	0	320	54,705	10.0 (yr 1–15)	1.3	—
	Year 30	78	121	320	500,967	6.0 (yr 15–30)	31.1	630.3
	Change	78	121	0	446,262	8.0 (yr 1–30)	29.8	—
With consumption function								
	Year 1	25	59	320	131,822	5.8 (yr 1–15)	0.0	—
	Year 30	55	68	320	433,999	2.8 (yr 15–30)	51.7	228.1
	Change	30	9	0	302,177	4.2 (yr 1–30)	51.7	—
Alternative tax policies								
Nonindexed taxes	Year 1	25	59	320	131,822	7.2 (yr 1–15)	0.0	—
	Year 30	66	98	320	612,262	3.8 (yr 15–30)	160.7	314.8
	Change	41	39	0	480,440	5.5 (yr 1–30)	160.7	—
No interest write-off	Year 1	25	59	320	131,822	6.4 (yr 1–15)	0.0	—
	Year 30	72	131	320	583,547	4.4 (yr 15–30)	94.9	301.0
	Change	48	72	0	451,725	5.4 (yr 1–30)	94.9	—
No depreciation allowance	Year 1	25	59	320	131,822	6.6 (yr 1–15)	0.0	—
	Year 30	78	125	320	601,881	4.3 (yr 15–30)	78.8	309.8
	Change	53	66	0	470,059	5.4 (yr 1–30)	78.8	—
No investment tax credit	Year 1	25	59	320	131,822	7.1 (yr 1–15)	0.0	—
	Year 30	85	158	320	703,153	4.9 (yr 15–30)	51.8	358.2
	Change	60	99	0	571,331	6.0 (yr 1–30)	51.8	—

Table 5. Results of Thirty-Year Growth Simulation Beginning with a Typical Georgia Commercial Peanut Farm in 1979

		Acres			Discounted Real Net Worth		Federal Income Tax Rate (%)	Estate Transfer as % of Initial Net Worth
		Owned	Mortgaged	Operated	Total (1979/$)	% Annual Change		
Baseline								
	Year 1	100	234	580	189,673	8.1 (yr 1–15)	0.0	—
	Year 30	312	881	1,094	1,116,292	4.7 (yr 15–30)	48.1	38.1
	Change	113	647	514	926,619	6.3 (yr 1–30)	48.1	—
Initial tenure								
Full owner	Year 1	580	0	580	984,292	4.5 (yr 1–15)	25.1	—
	Year 30	825	1,634	3,460	2,790,137	2.9 (yr 15–30)	222.7	147.4
	Change	245	1,634	1,880	1,805,845	3.7 (yr 1–30)	197.6	—
Full renter	Year 1	0	0	580	72,406	11.6 (yr 1–15)	0.0	—
	Year 30	137	743	880	821,385	6.1 (yr 15–30)	22.1	753.0
	Change	137	743	300	748,979	8.8 (yr 1–30)	22.1	—
With consumption function								
	Year 1	100	234	580	189,673	6.1 (yr 1–15)	0.0	—
	Year 30	179	475	654	730,082	3.6 (yr 15–30)	43.3	257.9
	Change	79	241	74	540,409	4.8 (yr 1–30)	43.3	—
Alternative tax policies								
Nonindexed taxes	Year 1	100	234	580	189,673	8.0 (yr 1–15)	0.0	—
	Year 30	188	666	854	966,471	4.0 (yr 15–30)	164.0	343.8
	Change	88	432	274	806,798	5.9 (yr 1–30)	164.0	—
No interest write-off	Year 1	100	234	580	189,673	6.5 (yr 1–15)	0.0	—
	Year 30	186	588	774	821,120	4.1 (yr 15–30)	117.4	287.4
	Change	86	354	194	631,447	5.3 (yr 1–30)	117.4	—
No depreciation allowance	Year 1	100	234	580	189,673	7.3 (yr 1–15)	0.0	—
	Year 30	202	732	934	970,645	4.4 (yr 15–30)	85.1	335.5
	Change	102	498	354	780,972	5.8 (yr 1–30)	85.1	—
No investment tax credit	Year 1	100	234	580	189,673	7.9 (yr 1–15)	0.0	—
	Year 30	214	840	1,054	1,073,666	4.6 (yr 15–30)	55.7	367.8
	Change	114	606	474	883,993	6.2 (yr 1–30)	55.7	—

Table 6. Results of Thirty-Year Growth Simulation Beginning with a Typical Washington Palouse Commercial Winter Wheat Farm in 1979

		Acres			Discounted Real Net Worth		Federal Income Tax Rate (%)	Estate Transfer as % of Initial Net Worth
		Owned	Mortgaged	Operated	Total (1979/$)	% Annual Change		
Baseline								
	Year 1	211	494	1,280	359,139	8.5 (yr 1–15)	0.0	—
	Year 30	776	1,009	1,785	2,204,189	4.6 (yr 15–30)	26.3	368.5
	Change	565	515	505	1,845,050	6.5 (yr 1–30)	26.3	—
Initial tenure								
	Year 1	1,280	0	1,280	1,989,051	4.9 (yr 1–15)	36.0	—
Full owner	Year 30	1,798	4,161	5,959	6,340,068	3.3 (yr 15–30)	68.1	110.9
	Change	518	4,161	4,679	4,341,017	4.1 (yr 1–30)	32.1	—
	Year 1	0	0	1,280	111,465	13.0 (yr 1–15)	2.0	—
Full renter	Year 30	707	453	1,280	1,429,505	5.9 (yr 15–30)	18.6	811.0
	Change	707	453	0	1,318,040	9.3 (yr 1–30)	16.6	—
With consumption function								
	Year 1	211	494	1,280	359,139	7.1 (yr 1–15)	0.0	—
	Year 30	342	1,322	1,665	1,729,574	4.2 (yr 15–30)	13.4	298.1
	Change	131	828	385	1,370,435	5.6 (yr 1–30)	13.4	—
Alternative tax policies								
	Year 1	211	494	1,280	359,139	8.4 (yr 1–15)	0.0	—
Nonindexed taxes	Year 30	567	1,218	1,785	1,999,492	4.0 (yr 15–30)	194.8	339.4
	Change	356	724	505	1,640,353	6.1 (yr 1–30)	194.8	—
	Year 1	211	494	1,280	359,139	6.3 (yr 1–15)	0.0	—
No interest write-off	Year 30	285	1,100	1,385	1,455,560	4.0 (yr 15–30)	30.2	255.9
	Change	74	606	105	1,096,421	5.1 (yr 1–30)	30.2	—
	Year 1	211	494	1,280	359,139	8.0 (yr 1–15)	0.0	—
No depreciation allowance	Year 30	520	1,265	1,785	2,009,387	4.4 (yr 15–30)	27.1	340.8
	Change	309	771	505	1,650,248	6.1 (yr 1–30)	27.1	—
	Year 1	211	494	1,280	359,139	8.4 (yr 1–15)	0.0	—
No investment tax credit	Year 30	717	1,068	1,785	2,161,281	4.6 (yr 15–30)	26.1	362.4
	Change	506	574	505	1,802,142	6.4 (yr 1–30)	26.1	—

References

Fawcett, David, and Ted Thornton. "Typical Farm Data Series." Washington, D.C.: U.S. Department of Agriculture, ESCS, forthcoming.

Melichar, Emanuel. "Capital Gains versus Current Income in the Farming Sector." *Amer. J. Agr. Econ.* 61(1979):1085–92.

Tweeten, Luther. "Agricultural Policy Issues for the 1980's." *Agricultural Policy and Economics Issues,* vol. 2, no. 11. Oklahoma Coop. Extens. Serv. and Dep. Agr. Econ., Oklahoma State University, Nov. 1979.

Tweeten, Luther. "An Economic Investigation into Inflation Passthrough to the Farm Sector." Mimeographed. Dep. Agr. Econ., Oklahoma State University, 1980a.

Tweeten, Luther. "Farmland Pricing in an Inflationary Economy." Mimeographed. Dep. Agr. Econ., Oklahoma State University, 1980b.

Land Ownership Restrictions of the Midwestern States: Influence on Farm Structure

Philip E. Harris

Proponents of the family farm recently have been successful in getting some legislatures of midwestern states to pass laws that restrict the rights of aliens and corporations to control farm land (Morse, Reeves, Harl, p. 61). These laws are not the first to limit aliens in their rights to own real estate (Zagaris, pp. 38–39). For example, the common law rule in England prior to 1870 prevented aliens from acquiring good title to land without the king's approval (Blackstone, vol. 2, pp. 249–50). The reason for limiting rights of aliens made sense in the feudal system that existed when the common law rule arose. In that feudal system, the king granted land to lords (and the lords in turn granted land to lessor lords) in exchange for a commitment to furnish specified goods or services—including service in the king's army. An alien was likely not to have the necessary loyalty to the king to uphold his obligation to provide such services. Therefore, to reduce the risk of conveying land to a party who would fail to perform the services promised, the law eliminated aliens (except those approved by the king) from the class of people that could hold land. The logic behind the current interest in restricting land ownership is not so simple.

The primary objective of current laws that restrict the ownership of farmland by aliens and corporations is to influence farm structure by preserving the family farm (Minn. Stat. Ann. Sec. 500.24 (1), Supp. 1979; S.Dakota Compiled Laws Ann. Sec. 47-9A-1, Supp. 1979; Neb. Rev. Stat., Sec. 76-1501, 1976). There are important legal and practical limitations to the effectiveness of restrictive laws in attaining that objective. Some of those limitations are discussed in the second part of this article. The first part of this article summarizes the laws of the midwestern states that restrict the rights of aliens and corporations to control farmland.

Land Ownership Restrictions

The following are definitions of some key terms as used in this article.

A "family farm" is a farming unit that is owned and operated by people who are closely related by blood and/or marriage. A corporation, or any other business entity, will be included in the term "family farm" as long as the entity is engaged primarily in farming and is controlled by members of a family. The characteristic that most clearly distinguishes a family farm from other farms is that the members of the family have management control. That characteristic would be seen by most proponents of the family farm as an essential element without which many of the benefits of family farms would be lost. Another characteristic that distinguishes most family farms is that the majority, if not all, of the labor is performed by members of the family. While this characteristic is probably not as universally important to proponents of the family farm as the management characteristic, many people would be less favorable to protecting a farm where more than one-half of the labor was supplied by non-family members than to protecting farms on which family members provided most or all of the labor. The final characteristic that sometimes distinguishes a family farm is ownership of the farm land by the family. This characteristic is less common and probably would be viewed by most proponents of the family farm as not an essential element as long as the family farmer is assured of the availability of land to farm.

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"Corporations" will include corporations formed under the laws of any jurisdiction for the purpose of making a profit except those that are included in "family farms" as defined above.

"Aliens" will include only those people who are not U.S. citizens and who live outside the United States. Therefore, "resident" aliens—citizens of other countries who live in the United States—are not included.

Laws of Midwestern States

The restrictive laws enacted by the legislatures of the midwestern states are quite diverse in their approach to limiting corporate and alien ownership of farmland. The following summary of the laws of thirteen midwestern states is intended only to provide an idea of the types of restrictions used. Morrison and Krause, and more recently, Morse, Reeves, and Harl have thoroughly compiled and discussed the restrictive laws of all the states.

The following table shows that eight of the states whose statutes were examined directly prohibit corporate ownership of farmland and ten states either prohibit alien ownership of farmland or limit the amount aliens can own. Six states include businesses controlled by aliens in their prohibitions. Four states prohibit leasing farm land by aliens and corporations and seven states prohibit corporations from engaging in farming.

The exceptions to those restrictions are too numerous and varied among the states to be catalogued here. A few examples will be illustrative. The most common exception is for corporate ownership and use of farmland for research, production of seed stock, or similar activities. Some states allow corporations or aliens who owned land on the effective date of the law to retain the land they owned and, in some cases, to acquire more land to accommodate a reasonable rate of growth. Most of the states provide a period of time for an alien or corporation to divest land they are prohibited from owning or to become eligible to own the land.

In addition to the above restrictions, seven of the states require corporations, aliens, and

Table 1. Summary of Laws of Thirteen Midwestern States Restricting Agricultural Land Ownership

	Laws				
States	Prohibits Owning Agricultural Land[a]	Prohibits Leasing Agricultural Land	Limits Amount of Agricultural Land That Can Be Owned	Prohibits Farming	Requires Reports[b]
Illinois	A[c]				
Indiana			A[c] (320 A.)		
Iowa	C, A, AB	C			C[d], A, AB
Kansas				C	
Michigan					
Minnesota	C, A, AB			C	C[d], A, AB
Missouri	C, A, AB	A[e]		C	C[d], A, AB
Nebraska	C[f], A[c], AB				C[d]
North Dakota	C[d], A, AB			C[d]	A, AB
Ohio					A, AB
Oklahoma	C[g], A	C[g]		C[g]	
South Dakota	C	C	A (160 A.)	C	C[d], A[h]
Wisconsin	C		A, AB (640 A.)	C	

Note: "C" indicates the state has a law that applies to all corporations except family farm corporations unless otherwise noted; "A" indicates the state has a law that applies to nonresident aliens unless otherwise noted; "AB" indicates the state has a law that applies to businesses that are controlled by nonresident aliens.

There are a myriad of minor exceptions to the general prohibitions in the various states such as a divestment period, grandfather clauses, experimental uses, and others.

These reports are required of entities owning agricultural land and are in addition to annual corporate reports which are required by all of the states.

Resident aliens are subject to the law.

Family farm corporations are also subject to the law.

Law applies only to lease for more than ten years.

Law applies to all corporations that are incorporated under jurisdictions other than Nebraska (including family farm corporations) but does not apply to any corporations that are incorporated in Nebraska. Nebraska corporations cannot be controlled by aliens.

Family farm corporations that are incorporated under jurisdictions other than Oklahoma are subject to the law.

South Dakota just monitors reports required by the federal Agricultural Foreign Investment Disclosure Act of 1978.

alien-controlled businesses that are legally holding agricultural land to file an annual report detailing the background of the owners and their use of the property.

Limitations of the Laws

The major legal limitations on the states' restrictive laws are the federal constitution and international treaties (Morrison, p. 639). Morrison concludes that state laws which restrict the rights of resident aliens (e.g., Illinois, Indiana, and Nebraska) are less likely to survive a constitutional attack under the equal protection and due process clauses of the fourteenth amendment than laws which restrict the rights of nonresident aliens and corporations.

The reason for that distinction is that land ownership for a resident alien is a basic need similar to welfare benefits, employment by the state, and eligibility for a profession which the U.S. Supreme Court has held cannot be withheld on the basis of alienage. By contrast, nonresident aliens and corporations do not have the same basic need to own U.S. land and therefore can constitutionally be discriminated against if the state can show a "rational relationship" between those classifications and a legitimate state interest (Morrison, pp. 642–43).

There is a rational relationship between the two classifications (aliens and corporations) and the law's purpose of influencing the local economy. However, the state has a legitimate interest in influencing the local economy only if the federal powers over foreign relations and foreign commerce (U.S. Constitution Article I, Sect. 8) do not preempt the states' powers in those areas. Morrison concludes that the simple exercise of mechanical rules (such as the exclusion of aliens from ownership of land) has not been preempted by federal foreign relations activity (p. 649). Nor has the federal government preempted the foreign commerce field since it has ratified treaties which presume the validity of state legislation restricting the ownership of real estate (p. 652). Therefore, state laws restricting resident aliens' ownership of farm land are very likely to be held unconstitutional if tested in the courts, but such an attack would not invalidate the portion of the restrictive laws that limit the rights of nonresident aliens and corporations.

Treaties entered into by the United States are a part of the "supreme law of the land" (U.S. Constitution, Art. VI, para. 2) and thus override inconsistent state legislation. Many of the existing treaties grant rights to conduct business and to acquire land necessary for the operation of the permitted business. However, most treaties reserve the right to limit or exclude alien activity in exploitation of land which, if exercised, would validate restrictions on alien ownership of farmland. Furthermore, the treaties often expressly recognize the laws of states regarding their land. Therefore, state laws restricting alien ownership of farmland are likely to be consistent with treaties and not overridden by them.

Practical Limitations

Legal avoidance and illegal evasion. Laws restricting alien ownership of farmland can be legally avoided if aliens are not also prohibited from owning a controlling interest in a trust or business that owns farmland. Even if an alien is legally forbidden to own farmland indirectly, the law is difficult to enforce if several layers of corporations or fiduciaries are used to hide the identity of the beneficial owner. The same problem arises if a corporation is the beneficial owner of farmland. Iowa has attempted to solve this problem by requiring all conveyances of agricultural land (including leases for a period of five years or more) to be recorded and the beneficial ownerships of such conveyances to be disclosed (Morse, Reeves, Harl, p. 109). Zumbach and Harl discuss the limitations on a state's ability to pry information out of corporations that are incorporated in other states. They conclude that a federal reporting system (such as the Agriculture Foreign Investment Disclosure Act of 1978) would be more effective in penetrating the layers of corporations and fiduciaries to determine the beneficial owner (pp. 325–31).

Supply of family farmers. Proponents of the restrictive laws are likely to think that the income of family farmers will be increased by the laws as well as the number of family farms. They probably reason that the restrictive laws will reduce the price of land and therefore increase the net income to family farmers, which is the remainder of the revenue from farm products after the costs of all farm inputs are subtracted. The ability of restrictions on farmland ownership to raise the income of family farmers depends upon the elasticity of supply of family farmers.

It is reasonable to assume that the elasticity

of supply of family farmers is quite high. There is an annual flow of farm youth from Midwest farms to full-time off-farm jobs (Abourezk, p. 500). Because of this flow, the farm sector would not have to attract people from other lines of work to increase the number of family farmers but simply retain more of the youth who otherwise would leave the farms (Johnson, p. 182). These youth, already trained to operate a farm, are likely to be responsive to an increase in net farm income.[1] The high elasticity of supply of family farmers means there will be a large increase in the number of family farmers as a result of a small increase in net income of family farmers. The retention of youth who otherwise would have left the farm will continue until their competition for the net income from farming has driven that net income back to the level where farm youth at the margin would again be indifferent between leaving or staying on the farm.

The form which the competition among farm youth would take is in bidding for other factors of farm production until the costs of the other factors rise to the point that net income is reduced to the level stated above. Therefore, if the elasticity of supply of family farmers is high, barring or limiting alien and corporate purchase of farm land will have little effect on the net income of family farmers.

Motives of alien investors. The restrictive laws also may be less effective than expected because the threat to the family farm is less than expected. While this is not a limitation of the laws themselves, it should be considered with the other limitations so that the effect of the laws is not overstated. The issue is whether the motives of alien investors are compatible with family farming.

Before analyzing that issue, two factors that affect the current market value of farmland are delineated and discussed—the flow of income from the land and its expected value in the future. Those two factors are not independent since future value depends upon the expected flow of income in the future, which is correlated to the current flow of income. Despite their lack of independence, the two factors will be treated separately in this analysis because they provide independent reasons for purchasing farmland. The flow of income will be referred to as the productive value of farmland and the expected future value will be referred to as the speculative value of farmland.

The productive value and the speculative value of a given piece of land do not necessarily have to be owned by the same entity. For example, an investor could purchase fee title to farmland and lease it on a long-term basis to a farmer. The rental rate would reflect the land's productive value, while the purchase price would reflect the total of the land's productive, speculative, and other values. The investor could sell the speculative interest at any time by selling his fee title, subject to the rights of the farmer as lessor. The farmer could sell the productive value at any time by assigning the lease to another party. Therefore, for a given piece of land, its speculative and productive values can be severed from each other, transferred from one party to another, and recombined as the supply of and demand for them dictates.

The argument that aliens and corporations push farmland prices high enough to bar new family farmers from entering the industry implies that both the total price of land is too high and that the cost of severing the productive value from the speculative value is also too high. However, the transfer cost of acquiring the productive value of land from an investor who is only interested in the speculative value should not be prohibitive. The only parties involved in the transaction are the farmer and the investor. The investor will be concerned that the quality of the land is not diminished by the farmer's overuse or lack of care of the land. That problem could be dealt with in a two-party contract by stating a standard of use and care with which the farmer must comply or be liable for the resulting damages. The farmer will be concerned about having the right to farm the land for a period long enough to justify investing in equipment to farm the land. As the length of the agreement is increased, the farmer will acquire more of the speculative value because he or she will acquire the right to more of the future production on which the speculative value is based. Arriving at an agreeable length of time should not be an insurmountable problem, however, because the investor's time horizon is likely to be as long or longer than the period necessary to justify the farmer's investment in equipment. Furthermore, both parties can reserve the right to transfer their interest in the land to a third party.

[1] Johnson cites (on pp. 186–87) a study by Edward W. Tyrchniewicz and G. Edward Schuh of Purdue University which estimated the long-run elasticity of supply of unpaid family farm workers to be −3.26.

Perhaps potential new farmers would choose not to farm if they were not assured of having their land to farm for the period required to justify their investment in machinery. While the risk of having to find new land to lease or to change careers if their lease were not renewed certainly would reduce the attractiveness of farming, it would surely not be an absolute bar to farming since most of the alternative careers available to potential farmers have some, if not more, risk of being unavailable within the same period of time. For example, the changing supply of and demand for construction workers, engineers, or lawyers could force people in any of those careers to find employment in a different location or a different occupation.

The severability of the productive and speculative values of farmland is important in analyzing the compatibility of alien investment and family farming. To the extent aliens purchase land as an investment and not as a means of acquiring the commodity produced on the land, they will be interested only in maximizing the return on their investment.[2] Because aliens by definition do not reside in the United States and therefore cannot farm the land personally, their alternatives for realizing the productive value of their land are to (*a*) manage the farms themselves or by an agent and hire the necessary labor to farm the land, (*b*) rent the land on a crop-share basis, or (*c*) rent the land for cash. Given the investor's distance from the land, a cash lease would be the least expensive to supervise and for that reason may be the most attractive alternative. If the alien investor does choose to lease the land for cash and is willing to lease it for the period of time necessary to justify the investment in machinery, the alien investor is very little threat to the family farm. A crop-share lease takes some of the management away from the family farmer but for most of the proponents of the family farm, it probably leaves enough management with the family to satisfy the desire to preserve the family farm. Therefore, if the alien investor rents the land either for cash or a share of the crop, the fact that the land is owned by an alien rather than the family farmer or another American has little effect on the existence of the family farm (Currie et al.).

[2] Currie et al. found no desire among the foreign investors in Iowa farmland they surveyed to acquire the commodities from the land for foreign consumption (p. 129).

If the alien investor chooses to manage the farm and hire the necessary labor, the management of the farm would be severed from the labor to such an extent that most proponents of the family farm probably would consider the essential characteristic of the family farm to have been lost. Therefore, if a sufficient amount of land is purchased by alien investors and if a sufficient portion of them manage their land directly, then alien investors would pose a threat to the family farm. The portion of American farmland which alien investors must own and manage to become a serious threat to the family farm is subject to debate. Some ownership and management of farmland by aliens is likely to be compatible with family farming since working on an alien investor's farm may supplement the income of young family farmers during the years when they have more labor than can be effectively employed by their own capital and management.

Therefore, to the extent alien investors in American farmland are interested only in the return on their investment and do not manage the farm themselves or by an agent, they will have little effect on family farms. Consequently, the main effect of laws restricting alien investors in farmland would be to allow the family farmer to be an investor in land as well as a farmer. As Atkinson and Jones suggest (p. 62), with the increase in the size of farms, the assumption that the ownership and operation of family farms must be in one entity may no longer be valid.

Conclusion

There are some important limitations on the effectiveness of restrictive land ownership laws in preserving the family farm. Restrictions on resident aliens' rights are likely to be unconstitutional under the equal protection clause. The rights of nonresident aliens and corporations do not receive the same level of constitutional protection. Therefore, restrictions on the rights of nonresident aliens and corporations to own farmland are likely to survive a constitutional attack. While international treaties override inconsistent state law, state restrictions on farmland ownership are likely to be consistent with existing treaties and therefore valid.

Aliens can legally avoid restrictive laws if they are not prohibited from owning farmland

indirectly through corporations or fiduciaries. Enforcement of laws prohibiting indirect ownership is difficult on the state level because of the states' limited right to pry information out of corporations organized under the laws of another state. If the elasticity of supply of family farmers is high, the restrictive laws will have little effect on the level of income of family farmers. Finally, to the extent alien investors are not interested in acquiring the ommodity from the farmland and are not in-erested in managing the farm, they pose little ıreat to the family farm. If the threat of alien ıvestors to family farms is low, then laws estricting alien investments will do little to rotect the family farm.

These limitations of the restrictive laws can e explored more thoroughly as data become vailable from the various reporting laws. The mitations may prove to be so great that the enefits of the restrictive laws do not justify ieir cost.

eferences

ıbourezk, James. "Agriculture, Antitrust and Agribusiness: A Proposal for Federal Action." *S. Dakota Law Rev.* 20(1975):499–511.

ıtkinson, J. H., and Bob F. Jones. "Should Foreigners Own Land." *Foreign Investment in United States Agricultural Land.* Washington, D.C.: U.S. Senate Committee on Agriculture, Nutrition, and Forestry, Jan. 1979.

Blackstone. *Commentaries on the Laws of England.* Oxford: Clarendon Press, 1766.

Currie, Craig, Michael Boehlje, Neil Harl, and Duane Harris. "Foreign Investment in Iowa Farmland" *Foreign Investment in U.S. Real Estate.* Washington, D.C.: U.S. Department of Agriculture, Econ. Res. Serv., pp. 114–31, 1976.

Harris, Duane G., and William F. Hampel, Jr. "Bidding Potential of Foreign and Domestic Investors in Farmland." *Foreign Investment in U.S. Real Estate.* Washington, D.C.: U.S. Department of Agriculture, Econ. Res. Serv., pp. 103–13, 1976.

Johnson, D. Gale. *World Agriculture in Disarray.* London: Fontana-Collins, 1973.

Morrison, Fred L. "Limitations on Alien Investment in U.S. Real Estate." *Minn. Law Rev.* 60(1976):625.

Morrison, Fred L., and Kenneth R. Krause. *State and Federal Legal Regulation of Alien and Corporations Land Ownership and Farm Operation.* Washington, D.C.: U.S. Department of Agriculture, Econ. Res. Serv. Rep. 284, May 1975.

Morse, Rolland L., H. Clyde Reeves, and Neil E. Harl. "State Controls and Reporting Requirements." *Monitoring Foreign Ownership of U.S. Real Estate: A Report to Congress,* vol. 1, pp. 58–116, forthcoming.

U.S. Department of Agriculture. *Foreign Ownership of U.S. Agricultural Land.* ESCS Agr. Econ. Rep. 447, Feb. 1980.

Zagaris, Bruce. *Foreign Investment in the United States.* New York: Praeger Publishers, 1979.

Zumbach, Steven E., and Neil E. Harl. "Anonymity and Disclosure in Ownership Reporting Systems." *Foreign Investment in U.S. Real Estate.* USDA Econ. Res. Serv., pp. 320–40, 1976.

Sociological Aspects of Farm Size: Ideological and Social Consequences of Scale in Agriculture

William L. Flinn and Frederick H. Buttel

The issues of farm size and the wide range of institutional arrangements relating to the scale of agricultural production are among the most interesting areas of interchange between agricultural economists and their colleagues in rural sociology and associated disciplines. The renewal of debate over the structure of agriculture during the past decade raises such broad questions about alternative futures for agricultural organization in this society that representatives from no single discipline—agricultural economics, rural sociology, for example—can provide all the necessary guidance. The purpose of this paper will be to take some necessary interdisciplinary steps by setting forth several sociological observations on the issues of scale and structure of agriculture which are informed by agricultural economics research.

The first portion of the paper discusses a number of ideological and value aspects of farm size. The second section consists of an abbreviated summary of research on the social consequences of farm size and mechanization for farm families, nonfarm people, and rural communities, while the final section advances several observations about political-economic aspects of farm size and their implications for the debate over agricultural structure.

Agrarian Values and Ideological Aspects of Farm Size

One need not be a social scientist to realize the pervasive influence of Jeffersonianism and its ideological descendant, which we term agrarianism. Our previous research (Buttel an Flinn 1975), using a 1971 statewide rando sample of Wisconsin residents, has indicate clear majority support for attitudinal stat ments relating to agrarianism and the famil farm. For example, more than 80% of respo dents agreed that the "family farm is ver important to democracy." Favorable attitude toward agrarianism and the family farm wer most strongly supported among older peopl and among persons with low education fro farm origins and from rural places of res dence. These data, however, reveal some re sons why the "general public" has not fr quently mobilized around the issue of far size and the family farm; these generall favorable attitudes toward the family farm a not strongly held, as evidenced by the fact th majorities or near-majorities of responden tend to "agree" (rather than "strong agree") with pro-family farm attitudes.

It is not surprising that farm operators a even more likely than the general public express values favorable toward the fami farm (Flinn and Johnson). Older, less well-e ucated, and smaller-scale farmers (with sca measured in terms of number of acres a gross farm income) are most likely to agr with statements supporting agrarianism a the family farm. More recent data from Ne York State also indicate that small-scale far ers are more likely than larger-scale farmers disapprove of corporate agriculture and favor prospective government commodi programs that would disproportionately be efit small producers (Buttel; see also Butt Harris, Powers).

Thus, there is an overarching social cla contour to the ideological issues of farm si and the family farm. Small farmers and lo income segments of the general public a more sympathetic with preserving the fami farm and blocking corporate penetration of a

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riculture than are relatively privileged farmers and nonfarmers. In addition, there is evidence that positive attitudes toward the family farm and small-scale agriculture are tied to a general critique of the social order as articulated in terms of alienation, powerlessness, and political cynicism (Buttel and Flinn 1976).

Farm Size, Values, and Political Ideology

After a nearly ten-year period of dormancy, rural sociologists have begun to resume their work on the attitudes and ideologies related to farm size and structure. For example, Coughenour and Christenson have empirically examined a variant of the "small is beautiful" thesis by relating farm size to attitudes about personal well-being, community well-being, and perceived adequacy of services. They found virtually no evidence that small farmers are more satisfied than large farmers. In fact, the small differences that do emerge in these data suggest that large-scale farmers express higher levels of perceived well-being than small-scale farmers do. This tendency should not, however, obscure the fact that small operators typically have a high level of attachment to (or a relatively "noneconomic" orientation toward) agriculture (van Es and McGinty). Their sources of dissatisfaction as revealed in the Coughenour and Christenson study do not, of course, derive from negative attitudes about operating a small farm per se, but rather from an inability to support their families from these modest-scale farms.

Two of the more important social and policy issues in agriculture during the past decade are the effects of large agribusiness firms on farmers and the desirability of federal commodity programs. On each of these issues we can see substantial cleavages among farmers from different size-of-farm classes. Data from a random sample of farm operators in Michigan (Buttel, Harris, Powers) have demonstrated that the level of gross farm income is inversely correlated with both cynicism about agribusiness and advocacy of price supports. In general, small farmers are more politically liberal and more cynical about agricultural organization than are large farmers. Large farmers, on the other hand, are much less favorably inclined toward government "interference" in the economy—be it by regulating agribusiness firms, providing social welfare benefits such as public jobs or national health care programs, or undertaking commodity stabilization/price support programs. The tendency for small farmers to show greater favor for federal commodity programs represents something of an irony. Insofar as price supports and related programs may tend to benefit large operators differentially (Schultze, Raup), small farmers, because of their relatively liberal political commitments, may be unable collectively to develop social policies that would be in their own interest (Gardner, Gardner and Pope, Schultze).

Social Consequences of Scale in Agriculture

Much of the work of the pioneering rural sociologists (for example, Kolb and de Brunner) was devoted to determining how relentless increases in the scale of production agriculture had affected rural people and rural communities. Although this research did not return a unanimous verdict, it was substantially colored by a concern that the major forces affecting agriculture did not confer benefits and costs on rural and agricultural people in a socially or economically even fashion. Most of this incipient questioning of structural change in agriculture abated during the late 1950s and 1960s, only to be awakened with considerable vigor in the past decade. This phase largely began with a new edition of the classic work of Walter Goldschmidt on the effects of large-scale agriculture on rural communities in the Central Valley of California during the 1940s. Despite the crucial theoretical and methodological shortcomings of Goldschmidt's work (Goss, Sonka), nevertheless it has remained a fertile source of hypotheses.

Most research on the effects of farm size on rural people or rural communities is closely bound up with issues of mechanization or technological change (see Rodefeld 1980). Historic labor shortages (and relatively high wages) that accompanied the principal surge of agricultural development in the United States (primarily 1935–70) meant that a larger scale of agricultural operations usually was accompanied by deploying labor-saving technology rather than by hiring labor. However, it should be recognized that in several parts of the United States (particularly California), mechanization followed rather than led to large-scale agriculture. Existing large farms in California, many dating back to the Spanish land grants, employed many hired laborers

who only later were progressively displaced by labor-saving machinery (LeVeen).

The social consequences of increased scale and mechanization in agricultural production are, of course, exceedingly complex. First, these processes quite obviously involve both costs and benefits that are differentially captured or borne by societal groups. Because a simultaneous consideration of both costs and benefits (including their distributions across societal groups) has really never been accomplished within the context of a single research design, it is hazardous to generalize about the social consequences of changing scale of agricultural production. Moreover, the consequences of scale and mechanization vary decidedly according to the context—the kind of agriculture, the regional or local economic base, and the class relations among farmers—within which these changes occur (see, for example, Raup). Finally, farm size and mechanization are intimately related to a host of other structural changes in agriculture, and those other changes have independent but concurrent social consequences.

With these caveats, we may note that most rural sociological research on the consequences of farm size has been devoted to identifying two types of consequences: (*a*) changes in the socioeconomic characteristics of farm personnel, and (*b*) changes in the characteristics, especially population size and employment levels, of rural communities. At risk of overgeneralization, available research indicates a cluster of consequences of increased farm size and mechanization for the characteristics of farm people. The most striking and important is, of course, the effect on the numbers of farmers and farm workers. Scale and mechanization generally bring substantial declines in the number of farm people (including owner-managers, family laborers, hired agricultural workers, and their families). The decline in numbers is also generally accompanied by shifts in the types of these personnel; the proportion of family laborers (owner-managers and unpaid family labor) decreases, while the proportion of hired labor increases, particularly in those areas where the transition to large-scale industrial farming is well underway. Primarily because of the greater proportion of hired laborers, the overall characteristics of the farm population tend to shift toward concentration or inequality of land ownership, lower educational backgrounds, lower job and residential stability, lower levels of per capita income, and lower degrees of participation in community institutions such as voluntary organizations, churches, and the political system (Rodefeld 1974; Heffernan; Heffernan and Lasley; Fujimoto; Martinson, Wilkening, Rodefeld). Except for the clear economic gains captured by a shrinking group of larger farmers—whether they be owners or managers of large-scale industrial farms or owner-managers of large-scale family or tenant farms—the overall thrust of these research results is a hesitant or critical posture toward increases in farm size and mechanization.

A more potent critique of increasing scale in agriculture concerns its impacts on rural communities, especially relatively small communities, communities located in the relatively unurbanized "agricultural interior," and communities where inequality in the distribution of social resources such as education has left displaced farm personnel poorly prepared to enter the off-farm labor force (Raup). It is repeatedly observed that declines in the size of the on-farm work force yield declines in the population of rural communities and trade centers greater than the initial loss of farm people (Goss and Rodefeld) because larger farms and increased mechanization tend to undermine the sales and eventually the survival of retail merchants and other small businesses (Sonka and Heady). The trend is aggravated further by the constantly increasing level of sales necessary to support small business operations in rural communities (Ellenbogen). The consequence is the setting in motion of a downward multiplier or spiral of decline that has so far only been partially offset by the recent emergence of net metropolitan-to-nonmetropolitan migration.

Rural sociologists and their disciplinary colleagues thus have drawn a discouraging conclusion about the past and likely future course of structural change in U.S. agriculture. Yet it must be noted that these observations have not necessarily led rural sociologists to decry ongoing changes in the agricultural and rural sectors. Indeed, the center of gravity of the discipline until quite recently was one of passive acceptance of these phenomena. It was assumed, for the most part, that these consequences were inevitable and that the discipline should pursue research on compensatory mechanisms—community development, off-farm employment, rural industrialization, more efficient delivery of services—to help

ural residents cope with the adverse effects of ι changing agriculture.

Broader Political-Economic Implications of Scale in Agriculture

A number of incongruous pieces of observaion and evidence demand that rural social cientists adopt an essentiallly political-ecoıomic perspective in order to deal with hisoric and ongoing changes in the structure of J.S. agriculture. The majority of the U.S. population, especially farmers, sees the family arm as the ideal form of agricultural organizaion at the same time that family farms are leclining as a percentage of units and of sales n agriculture (see Rodefeld 1979, Emerson). As a result, there have been several adverse consequences for rural people and rural comnunities. Why, then, have these changes ocurred in the face of supportive social values and readily observable socioeconomic dislocaions attendant to structural changes in agiculture?

One possible answer is that large farm units re necessary to allow efficient production of gricultural commodities, which in turn fosers backward and forward linkages with inlustry and promotes the development of a maure industrial society. This answer must, however, be regarded as a half-truth in light of omparative evidence from other advanced ocieties. A number of industrial countries—otably Denmark, Italy, France, and Japan—ave reached fully industrialized status hrough routes that have not included nearly s much scale, mechanization, and dislocation n agriculture (Singelmann, Newby).

Other perspectives suggest that relentless ncreases in scale and mechanization in U.S. griculture have been due to either public polcy "mistakes," in which agricultural policy dministrators sincerely attempted to sustain he family farm but were unable to do so, or to leliberate attempts by policy makers to anihilate the family farm. Although both major 'ariants of this argument contain a small kerel of truth, each has major shortcomings that imit its utility in understanding structural hange in agriculture or in developing strateies to improve the condition of rural people. Agricultural policy clearly has a major role in he shaping structural change in agriculture Raup, Mann and Dickinson 1980), but the lifferent complexions of the agricultural systems of the United States and Denmark are not likely to be solely the result of different agricultural policies. Had the U.S. government taken a position more favorable or less favorable toward small-scale producers, these policies perhaps might have modified the transformations of U.S. agriculture but would not have qualitatively redirected them (Gardner).

Conceptual Imprecision

Before detailing what we think are more meaningful political-economic categories for understanding increasing scale in U.S. agriculture, we want to comment briefly on some of the limitations of two prevailing "theoretical" categories—scale and the family farm—and, by implication, a third—the corporate farm—that have generally been employed in the farm structure debate. The notion of scale in agriculture has a variety of distinct components that are often obscured when encompassed under a unilinear rubric. Most important, the mere notion of scale essentially ignores the question of social relationships of production. We must be much more specific about the social context of scale in agriculture—its property relations, social relations, labor relations, and technical relations—in order to understand historical and contemporary transformations in agricultural structure (de Janvry).

Many of the same criticisms can be made of the notion of the "family farm." This category is meaningless unless it is defined in historical or normative terms. If collectors of agricultural statistics can tell us confidently that the relative prominence of "family farms" has never fallen below 95%, we cannot say much about change in agriculture except that these "family farms" have become larger and fewer in number. With such an indeterminate definition of the family farm, the notion of the "corporate farm" becomes the only alternative reference point. Because we have defined the family farm so imprecisely, there is often misplaced emphasis on the prevalence and economic power of corporations in agriculture. A misplaced emphasis on corporate farming often leads to an erroneous assumption that if corporations were banned from agriculture, the problems of the family farm would cease to exist. We argue that barring nonfamily corporations from agriculture would have only partial, albeit significant, effects on many of the

consequences of increasing scale in agriculture, as Raup, no friend of corporate agriculture, has warned.

Family Farming As Independent Commodity Production

We believe that the notion of "independent commodity production" must serve as a conceptual benchmark for reaching a historical understanding of the political economy of agriculture. Independent commodity production can be defined as an agricultural production enterprise (or a system, where such production dominates) in which: (*a*) there is family ownership of land and other capital items plus entrepreneurial control of the allocation of this capital, (*b*) the majority of labor is provided by family members, (*c*) the farmer is largely or fully commercial and interacts in competitive factor and product markets, and (*d*) the farm family subsists primarily on farm income and home-produced commodities.

Several important concepts parallel the notion of independent commodity production. The first concept is differentiation, the tendency in a market economy for some family farmers to be differentially efficient and productive, to have unequal access to inherited wealth, and to be unequally able to accumulate profits. Differentiation primarily implies that disparities in the extent of property ownership will tend to increase. Many mechanisms can accelerate differentiation, including the "treadmill of technology" (Cochrane, LeVeen) and state policies biased in favor of more privileged farmers (Mann and Dickinson 1980).

The second concept is reproduction, the extent to which family farmers as a group have the means to reproduce the key relationships of independent commodity production. Reproduction is a logical extension of differentiation because reproduction will be most problematic for those least able to accumulate profits; thus, if families cannot earn sufficient incomes from the farm alone and must rely primarily on off-farm earnings, the family farm is only partially able to reproduce itself.

Differentiation and reproduction together imply a third concept, that of transformation: qualitative changes in the nature of family farming so that substantial numbers of farms no longer approximate the characteristics of independent commodity production. Ther are two extremes of transformation. The fir is the total failure of the farm family to repro duce itself; the family is forced to leave th farm because of very low returns or forecl sure. At the other extreme emerge the types relations earlier (and loosely) called corporat or large-scale industrial farming; enough cap tal is accumulated to dictate that the farme hire labor for most farm tasks on his large scale farm. There are also, of course, interme diate aspects of transformation as the famil farm begins to depart substantially from all c most of the characteristics of independer commodity production. While continuing t be "owner-operated"—the current definitio of supposed family farming—the farm ma nonetheless undergo significant changes in it social relations of production and exchange For example, the logical extension of produc tion contracts, with many entrepreneurial an management functions surrendered to the con tractor, may be the reduction of the famil farmer to a role little different from a "piece worker" (Davis).

One of the major forces leading to the trans formation of independent commodity produc tion is the dualism between farmer and lan owner in a system of private property in ag riculture, even when both roles are largel fused within the same farmer or family. Th most dramatic recent manifestation of th farmer-landowner distinction is the rapid infla tion of farmland prices as the benefits fro technological change and commodity pro grams have become capitalized in the price land. While directly benefiting absentee own ers of farmland, farm owner-managers hav been adversely affected through increase taxes, rents, and interest payments. The onl way a family farmer can benefit from lan inflation is, ironically, by ceasing to become farmer, i.e., by selling out and realizing capit gains through inflated land prices. This is th final and most compelling instance of th heretofore concealed antagonism between th farmer and landowner. Although not so dra matic as rapid land inflation, another impo tant consequence of farmer-landowne dualism is the increasing proportion of U.S farmland that is rented and absentee-owne (Rodefeld 1979). While land rental obviousl is a strategy to reproduce the family far through expansion, the result is a significar transformation in the character of independer commodity production.

The Dialectic of the Family Farm

Even though their farm size structures vary so greatly and their agricultural histories encompass a wide range of farm enterprise types, the social relationships of industry have failed to become fully manifest in agriculture in all the advanced industrial societies. In view of the fact that agriculture is one of the last sectors where a substantial amount of production is organized under relationships akin to the independent family farm, the intriguing question is not why so many have left the farm, but why so many have stayed!

There are several answers to this latter question. Because agriculture in temperate climates is tied to the seasons, there is an inherent excess of production time (when capital is tied up in fixed investments) over labor time. Under these circumstances, production agriculture remains unattractive to large-scale capital except in cases, such as irrigated areas of California, where technological advances allow virtually year-around production (Mann and Dickinson 1978).

Agriculture thus has been left primarily to "family farmers," and the inherent characteristics of farm families as independent commodity producers, once in place on the land, insure a high level of persistence and tenancy. Farm families can be viewed essentially as labor management systems in which the labor of family members is allocated between farm and nonfarm tasks to maximize the economic welfare of the family as a whole. The availability of family labor, generally on an unpaid basis, enables the family farm to absorb market downturns that might drive corporate-operated farms out of agriculture. The family farm also involves immobility of fixed capital, because of a high degree of attachment to the land and to farming as a way of life.

A variety of phenomena thus combine to comprise what we might call the dialectic of the family farm. On one hand, there are constant tendencies toward differentiation, concentration, and transformation of independent commodity production which are accelerated by economies of scale, government policies that reduce risk or perhaps disproportionately benefit large producers, and mainstream agricultural research. On the other hand, there are several factors inherent in the structure of agriculture and farm families (e.g., risk, the nonidentity between production and labor time, internal diseconomies of scale, immobility of fixed capital, and certain aspects of government agricultural policy) that combine to mitigate against the wholesale transformation of the family farm (Stanton, Mann and Dickinson 1978). Returning to our original question of farm size, we can see that scale in agriculture is an intervening variable in this dialectic of the family farm. Scale is at once a mechanism for the reproduction of the family farm as well as a mechanism for its differentiation and transformation. The ability of some farm families to absorb the technical and social changes that lead to scale in agriculture is widely recognized (Nikolitch). This ability does not, however, derive solely from the organizational superiority of the family farm in a narrow sense but rather, at least partly, from farmer "self-exploitation" and exploitation of unpaid family labor, as Lianos and Paris have put it (see also Barkley). Farmers often invest in labor-saving technology and additional farmland in order to remain in agriculture, typically at the expense of current family income (Raup). Yet, there are limits to the levels of technological development that can be absorbed by family-owned businesses. Stanton, for example, contends that the 300-cow herd represents a ceiling of scale for family-operated dairy farms in New York State. More important, as noted by Raup and Breimyer, the large-scale "family" or "larger-than-family" farm made possible by mechanization exhibits a number of vulnerabilities—particularly difficulties in intergenerational transmission and in adapting to market downturns. Their observation is that these large family-owned businesses, rather than small farms, will be most rapidly consolidated into large-scale industrial farms with absentee owners.

W(h)ither the Family Farm?

Increased scale does not imply the disappearance of the family farm, but neither does the increasing scale of contemporary family farms guarantee that these farms will continue to exist in classical form. Indeed, the transformation of the family farm from independent commodity production to a status that combines elements of the role of capitalist (employer of labor) and worker (forfeiting of entrepreneurial functions, off-farm employment, etc.) lies at the heart of some of the adverse effects experienced by rural people and communities.

Public attention recently has been focused on "structure issues" and "structure policy" in agriculture (ESCS), much of this attention having been prompted by nonfarm public interest groups. These groups have presented a strong case that there would be substantial potential benefits that would accrue to returning to a smaller scale of agricultural production, without adversely affecting levels of productivity and economic efficiency. The effects that these arguments will have are difficult to anticipate. On one hand, there has been fostered a long-overdue reassessment of the social costs of American agricultural development. On the other hand, one senses that these groups' overarching image of desirable social change often is a return to some imagined utopia of independent commodity production. In a very practical sense, however, we will not have the option of "going back." The larger economy and society have developed to the point that it is inconceivable that government policy could have sufficient leverage to overcome the forces behind differentiation and transformation of the U.S. agricultural structure (Walker).

While we cannot go back, this does not entirely foreclose possible future options. Nevertheless, this search for options must take account of the realities of the structure of agriculture in an advanced industrial society. Farmers and their spokespersons in public interest organizations must begin to grapple with the dominant forces of the dialectic of the family farm. For example, they must recognize that government assistance to the small farm will not likely be sufficient to alter substantially ongoing trends because of the farmer-landowner dualism discussed previously.

We suggest that one of the potentially most useful areas of activity would be to deal with the role of private property in land in accelerating the transformation of the family farm. Institutional modifications such as land banking and land trusts potentially can enable farmers and their communities to insulate themselves partially from many of the relentless forces of differentiation and concentration that operate through the market for private property in land. There also may be increased potentials for cooperatives in agriculture, perhaps centering around machinery sharing or cooperative operation of on-farm fuel production facilities. Another potentially exciting strategy is the development of local markets for agricultural produce, which could have a useful rural development role as well. However, the question must remain whether farmers will be ideologically predisposed to embrace these unconventional alternatives, as we alluded to at the outset of this paper. In sum, scale and organization of agriculture are political-economic questions that require political-economic strategies cognizant of the major social forces affecting agriculture.[1]

References

Barkley, Paul W. "A Contemporary Political Economy of Family Farming." *Amer. J. Agr. Econ.* 58(1976): 812–19.

Breimyer, Harold F. *Farm Policy: 13 Essays*. Ames: Iowa State University Press, 1977.

Buttel, Frederick H. *Agricultural Structure and Agricultural Policy: A Preliminary Report on the Values and Preferences of New York Farmers*. Cornell Rural Soc. Bull. Ser. No. 109, Nov. 1979.

Buttel, Frederick H., and William L. Flinn. "Sources and Consequences of Agrarian Values in American Society." *Rural Soc.* 40(1975):134–51.

———. "Sociopolitical Consequences of Agrarianism." *Rural Soc.* 41(1976):473–83.

Buttel, Frederick H., Craig K. Harris, and Sharon Powers. "Farm Size, Structure, and Political Ideology." Paper presented at the annual meeting of the American Sociological Association, New York, Aug. 1979.

Cochrane, Willard W. *Farm Prices*. Minneapolis: University of Minnesota Press, 1958.

Coughenour, C. Milton, and James A. Christensen. "Is Life on the Small Farm Beautiful? Agricultural Structure and Quality of Life in the United States." Paper presented at the V World Congress for Rural Sociology, Mexico City, Aug. 1980.

Davis, John Emmeus. "Capitalist Agricultural Development and the Exploitation of the Propertied Laborer." *The Rural Sociology of the Advanced Societies*, ed. F. H. Buttel and H. Newby. Montclair, N.J.: Allanheld, Osmun & Co., 1980.

de Janvry, Alain. "Social Differentiation in Agriculture and the Ideology of Neopopulism." *The Rural Sociology of the Advanced Societies*, ed. F. H. Buttel and H. Newby. Montclair, N.J.: Allanheld, Osmun & Co., 1980.

Ellenbogen, Bert R. "Service Structure of the Small Community: Problems and Options for Change." *Communities Left Behind*, ed. North Central Regional Center for Rural Development. Ames: Iowa State University Press, 1974.

Emerson, Peter M. *Public Policy and the Changing Structure of American Agriculture*. Washington, D.C.: U.S. Congress, Budget Office, 1978.

[1] The original, expanded version of this paper is available as Rural Soc. Bull. No. 114, from the Department of Rural Sociology, Cornell University, Ithaca, N.Y. 14853, c/o F. H. Buttel.

Flinn, William L., and Donald E. Johnson. "Agrarianism among Wisconsin Farmers." *Rural Soc.* 39(1974):187–204.

Fujimoto, Isao. *The Communities of the San Joaquin Valley: The Interrelations among Farming, Water Use, and Quality of Life.* Dep. Appl. Behavioral Sci., University of California, Davis, 1977.

Gardner, Bruce L. "Public Policy and the Control of Agricultural Production." *Amer. J. Agr. Econ.* 60(1978):836–43.

Gardner, B. Delworth, and Rulon D. Pope. "How Is Scale and Structure Determined in Agriculture?" *Amer. J. Agr. Econ.* 60(1978):295–302.

Goldschmidt, Walter. *As You Sow.* Montclair, N.J.: Allanheld, Osmun & Co., 1978.

Goss, Kevin F. "Review of Goldschmidt, *As You Sow.*" *Rural Soc.* 44(1978):802–6.

Goss, Kevin F., and Richard D. Rodefeld. "Farming and Place Population Change in Michigan, 1930–1970: An Exploratory Analysis." Paper presented at the annual meeting of the Rural Sociological Society, Madison, Wis., Aug. 1977.

Heffernan, William D. "Sociological Dimensions of Agricultural Structure in the United States." *Soc. Ruralis* 12(1972):481–99.

Heffernan, William D., and Paul Lasley. "Agricultural Structure and Interaction in the Local Community: A Case Study." *Rural Soc.* 43(1978):348–61.

Kolb, John H., and Edmund S. de Brunner. *A Study of Rural Society.* Boston: Houghton Mifflin & Co., 1952.

LeVeen, E. Phillip. "The Prospects for Small-Scale Farming in an Industrial Society: A Critical Analysis of *Small is Beautiful.*" *Appropriate Visions,* ed. R. C. Dorf and Y. L. Hunter. San Francisco: Boyd and Fraser, 1978.

Lianos, Theodore P., and Quirino Paris. "American Agriculture and the Prophecy of Increasing Misery." *Amer. J. Agr. Econ.* 54(1972):570–77.

Mann, Susan A., and James M. Dickinson. "Obstacles to the Development of a Capitalist Agriculture." *J. Peasant Stud.* 5(1978):466–81.

———. "State and Agriculture in Two Eras of American Capitalism." *The Rural Sociology of the Advanced Societies,* ed. F. H. Buttel and H. Newby. Montclair, N.J.: Allanheld, Osmun & Co., 1980.

Martinson, Oscar B., E. A. Wilkening, and R. D. Rodefeld. "Feelings of Powerlessness and Social Isolation among 'Large Scale' Farm Personnel." *Rural Soc.* 41(1976):452–72.

Newby, Howard. "The Rural Sociology of Advanced Capitalist Societies." *International Perspectives in Rural Sociology,* ed. H. Newby. London: John Wiley & Sons, 1978.

Nikolitch, Radoje. "The Individual Farm Family." *Size, Structure and Future of Farming,* ed. A. G. Ball and E. O. Heady. Ames: Iowa State University Press, 1972.

Perelman, Michael. *Farming for Profit in a Hungry World.* Montclair, N.J.: Allanheld, Osmun & Co., 1977.

Raup, Philip M. "Some Questions of Value and Scale in Agriculture." *Amer. J. Agr. Econ.* 60(1978):303–8.

Rodefeld, Richard D. "The Changing Occupational and Organizational Structure of Farming: Implications for Farm Work Force Individuals, Families, Communities." Ph.D. thesis, University of Wisconsin-Madison, 1974.

———. "Selected Farm Structural Type Characteristics: Recent Trends, Causes, Implications, and Research Needs." Report prepared for the Project on a Research Agenda for Small Farms, National Rural Center, Washington, D.C., 1979.

———. *The Direct and Indirect Effects of Mechanizing U.S. Agriculture.* Montclair, N.J.: Allanheld, Osmun & Co., 1980.

Schultze, Charles L. *The Distribution of Farm Subsidies.* Washington, D.C.: The Brookings Institution, 1971.

Singelmann, Joachim. *From Agriculture to Services.* Beverly Hills, Calif.: Sage Publications, 1978.

Sonka, Steven T. "Consequences of Farm Structural Change." Report prepared for the Project on a Research Agenda for Small Farms, National Rural Center, Washington, D.C., 1979.

Sonka, Steven T., and Earl O. Heady. "Farm Size, Rural Community Income, and Consumer Welfare." *Amer. J. Agr. Econ.* 56(1974):534–42.

Stanton, B. F. "Perspectives on Farm Size." *Amer. J. Agr. Econ.* 60(1978):727–37.

U.S. Department of Agriculture. *Structure Issues of American Agriculture.* ESCS Agr. Econ. Rep. No. 438, Washington, D.C., 1979.

van Es, J. C., and M. J. McGinty. "Relative Deprivation and Attachment to Farming: Some Further Considerations." *Soc. Rev.* 22(1974):259–70.

Walker, Neal. "Issues Involved in Formulating a Structures Policy for U.S. Agriculture." Paper presented at the Southern Agricultural Economics Association meetings, Hot Springs, Ark., Feb. 1980.

Critical Choices Relating to the Economic Structure of the Farming Sector: Discussion

Emerson M. Babb

In the coming years, important decisions about the structure of the farming sector will be made. These decisions, including making no change in current policies, will be based on facts or perceptions about the consequences flowing from alternative structures. The challenge to our profession, and to other professions concerned with agriculture, will be to provide information needed for decision making on a timely basis. We will be called upon to interpret our stock of research findings and to fill important gaps in our knowledge about farm structure relationships. The paper by Flinn and Buttel contains an excellent summary of the work by sociologists on farm structure and provides a basis for identifying the research that will be needed. Because of its scope, I will direct most of my comments to that paper.

The Flinn-Buttel paper is provocative and grapples with major issues in the farm structure debate. The authors indicate that sociologists would be divided on their interpretations of research findings and implications. Economists likewise will be divided. For example, it is unlikely that contracts have or will transfer virtually all managerial functions to the contractor firm. The consequences of separation of farm ownership and operation and of part-time farming may be less serious than suggested. The authors are gentle in their reminder to economists that the causes and consequences of changes in farm structure are not solely economic. They do not belabor the point that we sometimes take a narrow view of efficiency and ignore externalities.

The paper makes a number of important points. The first relates to the importance of defining what we want to preserve and why. Some of the authors' concerns about changes in structure are an outgrowth of their family farm definition. Second, changes in the overall characteristics of the farm population associated with the changing structure of agriculture may be as important as declines in the number of persons engaged in farming. The impacts of changes in farm population characteristics on rural communities are also important. We probably have directed too much attention to changes in farm numbers. Third, the sociologist's concepts of differentiation, reproduction, and transformation have economic content. In fact, these processes can be simulated. The process of change could be one research area where collaboration among economists and sociologists would be fruitful.

In sum, economists interested in farm structure will want to read the Flinn-Buttel paper. It provides a concise review of research by sociologists and their conceptual frameworks. The reader should obtain a copy of the paper prepared for the session, which is more than twice as long as the published version.

There is general support for Harris's conclusion that alien investment in agricultural land is not likely to threaten the family farm. He argues that land ownership restrictions have little effect on farm income. Income per farm may be affected, however, even if income in the aggregate is unchanged. The restrictions could influence farm size as well as the number of farms. The economic impacts of restrictions placed on corporate and alien land ownership appear to have been minor.

Eginton compares the financial performance of farm firms under alternative tax features using a budgeting process. His results are predetermined by the assumptions used, including the single objective of firm growth (the firm applies all additional income to growth). Projections might be more realistic and more useful if the model were restructured to analyze a variety of firm objectives, contained stochastic elements and permitted variation in assumptions about the firm.

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Critical Choices Relating to the Economic Structure of the Farming Sector: Discussion

Rulon D. Pope

Vo one can deny that structural issues are motionally charged, and there appears to be videspread concern that current changes are ot in the public interest. Further, as Flinn and Buttel indicate, there are interesting alliances etween farm and nonfarm groups interested in amily farms and related issues. It is ever be- ore us whether these concerns reflect a sub- tantive disenchantment with current institu- ions and policies, or whether the temporary osers in the tide of changing economic condi- ions are vocalizing their frustration. One is urious how these concerns respond to farm ncomes, as well. Judging from the perennial st of symposia, invited, and selected papers n structure, professional interest is inelastic nd structure will be of continuing concern in gricultural economics.

In a broad sense, all three papers deal with ne heart of the structural issue: the social and conomic characteristics of operators and wners, the number and sizes of farms, and ne ownership and control of resources. Each f the authors is to be commended for choos- ig timely and interesting aspects of the struc- ure issue.

Considering initially the Eginton paper, ough few details are given, it appears to be a icromodel of a cash-flow-constrained firm hich has few strategic choices to make. The onclusion that "tax concessions" encour- ged survival and expansion of farms is not nanticipated. Yet, one may question whether model with 6% rate of inflation and a sure ositive rate of return on assets with exoge- ously rising land prices has relevance to farm rowth issues under various taxation policies. hough I believe much could be discussed garding the strengths and weaknesses of the pproach, I would like to focus on the word concession" as used throughout the paper, emplified in the following quote:

> An alternative worthy of research is limitations on tax concessions such as interest payment write-off and depreciation allowances to set dollar amounts (as investment tax credits are now limited) to prevent continuing inflation from preferentially subsidizing superfarms to grow even larger.

It follows from competitive theory that profits may be taxed without distorting input use. Such a tax would imply input usage where the value of their marginal products equals input costs. Given a fixed marginal tax rate, this can occur only when each input's cost is subtracted from revenue and then taxed. What is the cost of capital? Theory suggests that interest plus depreciation costs must be included. I would argue that including a deduction for interest rate is not a "concession" promoting growth of farms. Reduction or elimination of the provision would lead to insufficient farm demand for capital. This in turn may lead to a rise in the rate of return to capital and a reduction in the wage rate as the capital/labor ratio falls. Thus I would disagree with much of the thrust of the conclusions of the paper.

The paper by Harris also treats an interesting and important topic. Some data are helpful in seeing the topic in perspective. More than half of all land in farms was operated by part-owners and this number appears to be increasing (Banks). About 30% of the farm and ranch land is owned by 1% of owners. Sole proprietorships and husband and wife owners account for about two-thirds of all private holding. Non-family corporations hold 2.4% of the farm and ranch land. Concerning the residency of purchasers of land, surveys indicate that 80% of the acreage purchased involved tracts from the same county as the purchaser, 14.5% from another county, 5.5% from another state, and .05% from outside the United States (USDA). The data also suggest that most of the states which have enacted legislation restricting ownership have a low incidence of either corporate (widely held) or alien ownership.

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Since the above data suggest that the economic impact of alien or corporate ownership (or restriction) is relatively low, it remains difficult to explain the actions of states passing this legislation on the grounds that farmers were feeling a measurable rise in land prices. Presumably, separation of ownership and operator are at the center of these motives. Over half of the U.S. land is already operated by part-owner farmers, suggesting widespread separation between ownership and operation. Further, returning to the Eginton model, if farms are constrained from efficient choices due to a cash flow constraint, then corporate and alien investment can be a boon to the food sector, as was foreign investment in the United States during the early and mid-nineteenth century.

It is not feasible to discuss the many possible motivations for these investors' recent attention to agricultural investment in the United States. Clearly, tax policies, exchange rates, expected incomes, and inflation rates are among the macroeconomic variables of interest. These must not only be considered with respect to the United States, but with respect to the entire international portfolio of investments (see Nuckton and Gardner, and Rausser, Schmitz, Warner, for a discussion). However, with the recent slowing in the rate of land appreciation, it will be interesting to see if there is a change in the magnitude of these investments.

The Flinn and Buttel paper is excellent and should raise our awareness of sociological issues, observations and perspectives. There is much for agricultural economists to ponder and debate in this paper regarding farm size: this is usually the case when we consider a broader social science perspective than our own. This debate should be centered on discussing pragmatic alternatives. As Friedman's "Free to Choose" exemplifies, we may disagree on means more violently than the goal. Finally, not only are our perspectives different, but our epistemological approaches differ as well. I believe most economists would be cautious in the interpretation of attitudinal surveys but have more faith in revealed preference. Yet these data are useful and it is important for economists to try to understand, e.g. why small farms support farm programs with more enthusiasm than larger farms. Why do low income urban dwellers support family farm notions when, relatively, they may have the most to lose from a policy which may raise food prices? It appears that economists will have little impact on policy unless we understand the issues from a sociological, political and economic perspective.

References

Banks, V. *Farm Population Trends and Farm Characteristics*. USDA Rural Dev. Res. Rep. No. 3, 1979.

Nuckton, C., and B. D. Gardner. "Foreign Investment in the U.S. Agricultural Land-Issues and Perspectives." *J. Amer. Soc. Farm Manag. and Rural Appraisers* 43(1979):40–49.

Rausser, G., A. Schmitz, and R. Warner. *Tax Implications of Foreign Direct Invest in U.S. Farmland*. Dep. Agr. and Res. Econ. Work. Pap. No. 88, University of California, Berkeley, 1980.

U.S. Department of Agriculture. *Who Owns the Land: A Preliminary Survey*. ESCS Res. Rep. #70, Washington, D.C., Sep. 1979.

Our Energy Transition: The Next Twenty Years

Wallace E. Tyner

About 150 years ago, Macaulay wrote the following passage regarding the prevailing mood of the time:

> We cannot absolutely prove that those are in error who tell us that society has reached a turning point, that we have seen our best days. But so said all who came before us, and with just as much apparent reason. . . . On what principle is it that, when we see nothing but improvement behind us, we are expected to see nothing but deterioration before us?

It is true that doomsday prophesies have been with us for hundreds of years. Has the time come for us to believe the prophets of doom, or can we see hope for improvement in the future? In forecasting our nation's energy future, there is ample cause for both despair and hope. The hope is premised on our ability to perceive accurately the nature of our energy problem and take prompt, effective actions to solve it. My own beliefs, which are reflected in the remainder of this paper, comprise a mixture of optimism and pessimism, which I like to characterize as guarded optimism.

Our current situation is that we are in an energy transition from petroleum fuels to alternate energy sources. The notion of energy transition is not new to our country. We have been through two previous energy transitions—one from wood to coal and the second from coal to oil and natural gas. Through the 1880s, biomass (primarily wood) was the major energy source in the United States. From the 1880s through the mid-1940s coal was the dominant energy source, and oil and natural gas have been the major energy sources since then. (Today, oil and natural gas constitute about three-fourths of our total energy consumption—one-half oil and one-fourth gas.) In the previous energy transitions, first coal and then oil and natural gas became the fuels of economic growth. The previous transitions involved not so much substitution of one source for another, but the use of the new energy source for new economic activity. That is the fundamental difference between our previous energy transitions and the current one. In the current transition, much of the attention is focused on decoupling economic growth and energy consumption (energy conservation) and on developing unconventional energy sources like oil shale, coal liquids, and biomass to substitute for oil. The era of cheap energy to fuel economic growth is gone; the question is what will the transition away from that era look like. That is the subject of this paper.

Because of all the interest in this energy transition, there have been a host of major multimillion dollar studies on our energy transition published in the last few years. The major ones are included in the references to this paper. While I have reviewed these studies in preparing this paper, I cannot discuss the results of each because of space limitations. Rather, I will reference specific points adopted from each study.

My procedure in addressing this very complex question in such a brief paper will be to first discuss the technical and economic potential of some major energy alternatives and then to integrate the separate pieces into a personal view of this transition. Once this is completed, I will discuss some of the policy issues related to the energy transition.

Conservation and Energy Consumption

Forecasting demand for anything twenty years into the future is always difficult, but forecasting energy demand twenty years hence borders on soothsaying. From the 1920s through

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the 1960s the real price of energy fell, yet the energy gross national product (GNP) ratio also declined during that period (Resources for the Future). That is, even with declining energy prices, the use of energy per unit of GNP fell with GNP growing at 3.1% and energy consumption growing at 2.5%, or 80% as fast. In the 1970s energy prices began rising in real terms, so we would expect the energy/GNP ratio to decline reflecting the higher energy prices. The question is how much will it decline over the next twenty years. To accurately answer this question we would need to understand thoroughly the feedback relationships between energy and GNP and to have reliable price and income elasticity estimates for each major energy source. (The CONAES study does the best job of estimating these elasticities and incorporating them in demand projections.) Furthermore, we would need to make assumptions about the rates of development and adoption of new energy conserving technologies.

One major problem in obtaining good long-run elasticity estimates is that much of the change in energy consumption requires a turnover in capital stock, which takes place over a long time period. We have yet to see all the conservation impacts on our economy resulting from the 1973 oil price increase. Turnover of the automobile fleet takes about eight years, and the housing stock is replaced in approximate fifty-year cycles. We have hardly begun to see the energy conservation induced by the 1979 oil price increases. In addition, energy-pricing policy is shifting from regulated prices to market prices and that impact is yet to be felt. Because these changes take so long to occur, we have no reliable statistical base from which to make demand projections.

Since the early 1970s, there has been a general decline in the level of all energy demand forecasts (table 1), regardless of the bias of the forecasters. The 1972 forecast of the low-growth advocates is about equal to the 1978 forecast of the high-growth advocates. None of these forecasts incorporate the doubling of oil price in 1979. Even if we disregard the two extreme groups of forecasters ("Beyond the Pale" and "Superstition") and seriously consider only the middle two groups (table 1), the difference amounts to about 30 quads or 15 million barrels of oil equivalent per day in 2000, which is 38% of our 1979 energy consumption. My own belief is that energy demand will increase in the range of 0 to 2.0% per year, with a most likely range of 1.0% to 1.5% per year. This implies a year 2000 energy consumption of 78 to 115 quads, with a most likely range of 95–105 quads.[1]

My forecasts are at the low end of "conventional wisdom," because I believe price-induced conservation will occur at increasing

[1] In arriving at these figures, I assume GNP will grow 2.0% to 2.5% per year, real energy prices will increase 2% to 3% per year, the income elasticity of energy is 1.0, and the own-price elasticity of demand is −.25 to −.50. These assumptions are consistent with the modeling results from the CONAES study (pp. 529–612). The 95 and 105 quad demand levels are lower than the RFF study and within the range of values used in the CONAES study. The EXXON forecast for 2000 is about 101 quads.

Table 1. Energy Demand Forecasts

Year of Forecast	Beyond the Pale	Heresy	Conventional Wisdom	Superstition
1972	125 (Lovins)	140 (Sierra)[a]	160 (AEC)	190 (FPC)
1974	100 (Ford zeg)	124 (Ford tf)	140 (ERDA)	160 (EEI)
1976	75 (Lovins)	89–95 (Von Hippel)	124 (ERDA)	140 (EEI)
1977–78	33 (Steinhart)	67–77 (NAS I, II)	96–101 (NAS, III, AW)	124 (Lapp)

Note: Amory Lovins put together this table showing the downward drift in forecasts. Figures represent total U.S. energy demand in year 2000 or 2010.
Source: *Science*, 208(June 1980):1353.
[a] Abbreviations: Sierra, Sierra Club; AEC, Atomic Energy Commission; FPC, Federal Power Commission; Ford zeg, Ford Foundation zero energy growth scenario; Ford tf, Ford Foundation technical fix scenario; Von Hippel, Frank Von Hippel and Robert Williams of the Princeton Center for Environmental Studies; ERDA, the Energy Research and Development Administration; EEI, Edison Electric Institute; Steinhart, 2050 forecast by Committee on Nuclear and Alternative Energy Systems (CONAES); AW, Alvin Weinberg study done at the Institute for Energy Analysis, Oak Ridge; Lapp, energy consultant Ralph Lapp.

ates in the future. Auto fuel economy will icrease even faster than government standards, and retrofitting will increase conservaion in the industrial and residential sectors.

iergy Supply

efore discussing each of the major supply itions, I will provide an overview of our curnt consumption, reserves, and energy reurces. Several important points emerge om examining our energy reserves and reurces (table 2). First, the magnitude of the serve and resource numbers clearly demonrates that we have huge amounts of energy serves and resources relative to our current nsumption. Our reserves could last from 70 170 years and resources could last from 250 320 years, assuming energy demand ineases at 1% per year and that we maintain r current level of import dependence.

Second, our energy problem is one of the screpancy between the forms of energy we e consuming and the forms we have in rerve domestically (table 3). Half our conmption of energy is oil and one-fourth tural gas, but our reserves of these sources e no more than 7% of total reserves. Our ergy problem is really the national security oblem of being dependent on the rest of the orld for half our liquid fuel needs. The ergy problem is best characterized as the nsition from our current patterns of energy pply and demand to patterns offering a bet- match between social cost and social value. (Included in social cost would be items such as the national security externality, environmental externalities, and risk premiums associated with some of the energy sources.)

Third, the extent of our energy reserves and resources depends critically upon whether or not the fast breeder reactor is developed. Uranium reserves and resources are multiplied by 60 to 100 times with the breeder reactor. In addition, we have vast reserves of thorium which can be used in a breeder cycle. However, large uncertainties remain and safety, waste disposal, and proliferation problems are not resolved for nuclear power.

Another point of interest regarding the reserve and resource numbers is that they do not include renewable resources (flows) such as solar, hydropower, and biomass. Use of renewables for a portion of our energy consumption would extend the stocks beyond the time periods indicated above. Potential for the major renewable resources will be discussed below.

Coal

With the recent publication of the WOCOL study and the Venice summit pronouncements on coal, interest in the future potential of coal is quite high. The WOCOL study estimated that coal could provide one-half to two-thirds of the increase in world energy consumption over the next twenty years. In line with the CONAES, RFF, OTA, and WOCOL studies, I estimate that U.S. coal production could grow at an average rate of 4%–5% per year

ıble 2. U.S. Energy Reserves and Resources

	Reserves			Resources		
source Type	Amount	% with LWR	% with FBR	Amount	% with LWR	% with FBR
al	5,747	89.2	21.5	58,614	87.0	41.1
l and NGL[a]	212	3.3	.8	694	1.0	0.5
s	224	3.5	.8	706	1.0	0.5
ale oil	0	0.0	0.0	6,084	9.0	4.3
iconventional gas	0	0.0	0.0	336	0.5	0.2
anium-LWR	257	4.0		910	1.4	
anium-FBR	20,510	—	76.8	76,200	—	53.4
tal-LWR[b]	6,640	100.0		67,344	100.0	
tal-FBR[c]	26,693		100.0	142,634		100.0

te: Our current energy consumption is about 78 quads per year plus 2 quads of wood.
irces: These estimates were derived from the CONAES, RFF, and FORD studies and other sources. The uncertainty in these imates is quite large, and other sources may show numbers that differ substantially from these. Generally, these numbers are about lway between the CONAES supply panel estimates and the RFF figures.
he oil and NGL resource numbers include enhanced oil recovery.
ight water reactor.
ast breeder reactor.

Table 3. U.S. Energy Consumption, Reserves, and Resources

Resource Type	Consumption	Reserves LWR	Reserves FBR	Resources LWR	Resources FBI
	%				
Oil and NGL	47	3	1	1	1
Natural gas	26	4	1	1	
Coal	19	89	22	87	4
Oil shale	0	0	0	9	2
Nuclear	4	4	76	1	5:
Others	4	—	—	1	1
Totals	100	100	100	100	10(

Sources: 1979 consumption from Department of Energy. *Quarterly Report: Energy Information*, Apr. 1980; reserves and resources fro table 2.

between now and 2000, which means that 2000 coal production would be 2.2 to 2.7 times the current level. Coal could increase from 19% to as much as 36% of total energy consumption by 2000. Coal exports may increase also.

However, the use of coal, whether it is directly combusted or converted to liquid or gaseous fuels, causes environmental problems. In addition, high levels of coal use may strain capital or equipment markets, cause transportation bottlenecks and social disruptions like the boom town growth in the West. Environmental problems include land reclamation, CO_2 effect, acid rain, air pollution, water pollution, and destruction of scenic beauty. Economically, coal-generated electricity compares favorably with oil-generated power even when all environmental control costs are included. For example, in Japan, where environmental control laws are strict, imported coal costs about $45 per ton and environmental costs add $35 a ton for a total of about $80 per ton compared to a cost of about $165 a ton for fuel-oil power generation. Comparison of coal to nuclear power is not so simple, and the answer depends very much on the assumptions used in the analysis. Generally, however, coal-generated power is as cheap or cheaper than nuclear power. The decision on the extent to which each will be used depends as much on the evaluation of nonmarket costs as on market costs.

Coal can substitute for liquid and gaseous fuels in several ways. We normally think of the most direct route technically, which is to liquify or gasify the coal. The CONAES study estimates that coal liquid and gas production in 2000 would be 2.3 and 3.5 quads, respectively, under the business-as-usual case. (No coal liquid or gaseous fuels are being produced commercially today in the U.S.) For the national commitment scenario these level reach 4.7 and 4.5 quads. Current estimates fo coal liquids cost range between $40 and $6 per barrel. Coal liquids plants will require a billion capital investment. High BTU coa synthesis-gas costs range between $3 and $ per million BTUs (1,000 cubic feet).

Another means of using coal to substitut for liquid fuels is by converting to electri vehicles and trains for motive power. Railroa electrification is one means of substitutin electricity generated by domestic coal or nu clear sources for diesel derived from importe oil. Assuming 1,000 route miles per year (new electrified track and a 2% annual growt in freight, preliminary research results ind cate that the oil savings by 2000 would b about 100,000 barrels per day or the equivalei of two syn-fuel plants.[2] The capital investmei required to achieve this savings is roughly th same as for an oil shale syn-fuel plant- $35,000 per barrel of daily capacity. Howeve the operating cost is considerably lower tha for a syn-fuel plant.

Use of electric vehicles also would brir about substitution of coal or nuclear power f(imported oil by displacing gasoline. By th year 2000, electric vehicles could achieve a oil savings of about 500,000 barrels per day, (ten syn-fuel plants (1 quad). The capital co in new plant and equipment for achieving th savings is estimated to be about $31,000 p new daily barrel of oil saved. Electric vehicl are projected to be competitive at gasoli costs slightly less than $2.00 per gall(($1980). (These preliminary results also con out of the Purdue energy transition study.)

[2] These are preliminary results from an ongoing study of energy transition by an interdisciplinary group at Purdue Univ sity. The unit of syn-fuel plant is a convenient measure to comp alternatives because many energy planners think in terms of t unit, which is about 0.1 quads/year.

We can expect to see increased efficiency in oal power generation over the next twenty ears by the successful development of echnologies employing cogeneration, fluidzed bed combustion, and Magneto-hydroynamic (MHD) coal power generation.[3] Inreased power generation efficiency will both ower the cost and reduce the primary energy equirement of coal-based power.

)il Shale

As indicated above, this nation has vast reources of oil shale, but the development of hale likely will not come close to the resource otential. The constraints on oil shale develpment will be environmental and social. The)TA oil shale study concluded that a 400,000 arrel per day (eight plants) industry could be eveloped by 1990 without serious difficulties, out that a 1 million-barrel-per-day industry vould unavoidably violate environmental air quality standards and cause serious economic and social disruption to the producing areas. Apparently, the environmental, economic, and social systems can accommodate a certain evel of development, but once this threshold s reached, the social costs of further develpment increase rapidly.

A 50,000-barrel-per-day oil shale plant is projected to cost $1.7 billion or $34,000 per daily barrel of capacity. Oil shale costs are projected to range between $35 and $60 per barrel depending on the crude oil price increase and rate-of-return used.

Oil and Natural Gas

The CONAES study projects U.S. oil production to range from 12 to 20 quads in 2000, depending on the level of national commitment to increased oil production. Most other studies project domestic oil production in 2000 including enhanced oil recovery to be lower than the 1979 production level of 17 quads. Domestic gas production in 1979 was about 19 quads. Domestic production of natural gas for 2000 ranges between 7 and 17 quads in the CONAES study.

Solar

The Harvard study projects solar energy to provide 4 quads by 1990. Solar energy utilization in the CONAES study is .0, 4.0, and 7.7 quads in the three scenarios. Direct use of solar is often more expensive than conventional sources. Without substantial economic incentives, solar energy will remain quite low over the next twenty years.

Nuclear

Nuclear energy is a large question mark for our country for the next twenty years and for the next century. The energy potential from nuclear energy is very high, yet so are the perceived social and environmental risks. The CONAES estimates for nuclear energy for 2000 are 12.5, 29.5, and 27.5 quads. Current nuclear power generation is about 3 quads. Even the CONAES business-as-usual case entails a quadrupling of nuclear power by 2000. Whether nuclear power will achieve that level or anything higher is an open question.

Biomass

The biomass energy category includes a wide variety of sources including wood, forage crops, crop residues, grains, and municipal solid wastes. Wood currently supplies about 2 quads of energy primarily in the forest products industry. The OTA biomass report attributes the highest potential within the biomass category to wood followed by forage crops. (Municipal solid waste was not included in this OTA report.) The most immediate biomass potential is for ethanol for gasohol from grains. Recent projections for ethanol capacity are for 60,000 barrels per day oil equivalent (1.2 syn-fuels plants) by 1983 (Meekhof, Gill, Tyner). By 1990, ethanol capacity could be 2 billion gallons per year of 145,000 barrels per day oil equivalent (about 3 syn-fuels plants or .3 quads). Whether or not grain alcohol production will increase beyond that level will depend on the impacts alcohol production has on feed/food prices and the policy response that occurs. Current research results indicate that alcohol production levels substantially higher than 2 billion gallons could cause corn prices to increase substantially (Meekhof, Tyner, Holland). By the mid 1980s, most authorities believe that cellulose conversion technologies will be commercially available to produce ethanol from crop residues, forage crops, wood, or municipal solid waste. It is too early to tell whether cellulosic biomass will be gassified, directly combusted, or converted to methanol or ethanol. The CONAES

[3] Magneto-hydro-dynamic power generation probably is more than twenty years away from commercialization, but has a good potential for the next century.

biomass estimates for 2000 are 0.1, 1.9, and 5.4 quads. (These figures exclude 2 quads of wood energy not currently included in U.S. energy statistics.) The most likely sequencing of biomass resources is an initial surge in grain alcohol followed by greater use of wood, municipal solid waste, and other cellulosic sources later in the 1980s.

Time Phasing of Supply Alternatives

In the very near term, the next five years, the most important changes in our energy picture will be increased conservation and ethanol production from grain. The 1979 oil price increase plus the phased deregulation of domestic oil and gas will induce much greater conservation than has occurred in the past. Within the next five years, there will be no commercial syn-fuels production from coal or oil shale, little use of electric vehicles, small increase in nuclear power, and a very low growth in solar energy. It takes six years to build a syn-fuel plant and ten to twelve years to bring a nuclear power plant to completion. A grain alcohol plant can be completed in two years, and I expect to see the equivalent of at least two syn-fuel plants of ethanol before the first coal or oil shale plant comes on stream.

Over the next decade, syn-fuel plants will come into production as will electric vehicles and rail electrification. By 1990, savings due to rail electrification likely will be less than one syn-fuel plant equivalent, but electric vehicle savings could be about three syn-fuel plants equivalent, roughly the same as biomass alcohol production. Oil shale syn-fuels could be as much as eight plants with roughly the same amount from coal gasses and liquids. By 1990, methanol from coal will be in production with the major use probably for turbine electric power generation (displacing fuel oil) for peaking power. Methanol from coal will grow fairly rapidly for stationary plant energy needs and perhaps for motive power as well.

In the 1990s, syn-fuels from coal will grow fairly rapidly along with solar, biomass, electric vehicles, and nuclear power. During the next two decades the absolute level of our dependence on foreign oil will decline very little, but the percentage of our dependence could decline from about 21% of total energy today to 13%–15% in 2000.

Because of the long lead times involved in the development of the energy alternatives, we face several critical choices in the next few years that will influence our ability to make the transition away from oil to other energy sources. We have already begun to deregulate oil and natural gas prices—steps which are absolutely essential if we are to achieve the conservation and alternative fuels development levels outlined in this paper. I think we should go further and place a tax on crude oil to internalize the national security externality caused by our dependence on oil. A crude oil tax would reduce demand growth as well as stimulate development of energy alternatives.

The other major choice we must make over the next decade is between the economic potential, environmental disruption, and societal risks associated with coal power and nuclear power. We will need some of each, but the choice concerns emphasis. I expect we will spend the next five to ten years developing both coal and nuclear power, but during that time we will have to decide how best to handle the externalities and risks imposed by each of these major power sources.

Table 4 summarizes where I think we are likely to be in the year 2000 for two demand levels. Note that I do not expect us to be on either a "hard" or "soft" path exclusively, and I reject the notion that "hard" and "soft" paths are mutually exclusive options. We will have some of each, with the "hard" path being dominant over the next two decades.

When we reach the vantage point of the year 2000, I hope we will be able to look back and see that we have developed to some extent the wide variety of energy sources we have discussed here including oil shale, coal syn-fuels, electric motive power, nuclear power, solar and biomass. If that is the case, we will be in a much better position in the year 2000 to project to 2020 than we are in today. My own feeling (from the 1980 vantage point) is that nuclear and solar energy (perhaps strange bedfellows) will provide much of the growth in energy from 2000 to 2020 and beyond. We may not be able or willing to greatly expand the syn-fuels industry or biomass because of the serious environmental degradation that could occur. Synthetic liquid fuels may be only transition fuels. To the extent that we are not able or willing to expand nuclear power, coal-based power is the most likely alternative. If that becomes the case, growth in coal-based syn-fuel development almost certainly will be limited and conservation and solar alternatives become much more important.

ble 4. Energy Supply and Demand for 2000

source pe	1979 Quads	1979 (%)	2000 (Demand = 95) Quads	2000 (Demand = 95) (%)	2000 (Demand = 105) Quads	2000 (Demand = 105) (%)
and NGL	20.4	25.5	12	12.6	14	13.3
tural gas	19.2	24.0	11	11.6	13	12.4
al[a]	15.1	18.9	35	36.8	37	35.2
clear	2.8	3.5	8	8.4	10	9.5
ale oil	0.0	0.0	1	1.1	1	1.0
othermal	0.0	0.0	1	1.1	1	1.0
lar	0.0	0.0	2	2.1	3	2.9
mass[b]	2.0	2.5	4	4.2	5	4.8
dro and other	3.0	3.8	5	5.3	5	4.8
imports	16.6	20.8	14	14.7	14	13.3
s imports[c]	0.9	1.1	2	2.1	2	1.9
Total	80.0	100.0	95	100.0	105	100.0

rce: Data for 1979 are from Department of Energy. *Quarterly Report: Energy Information*, Apr. 1980. Projection's are the author's.
1979 coal production actually was 17.4 quads, with 1.7 quads exported and 0.6 quads change in stocks. Year 2000 coal numbers ude synthetics.
iomass production and consumption, primarily wood in the forest products industry, currently is not included in official DOE istics. The 2 quads of biomass explains the different between the DOE 78 quads and the 80 quads shown here.
atural gas imports in 1979 actually were 1.2 quads. The figure is adjusted here to make production plus imports balance with sumption.

Clearly, this has been a personal view of our ergy future and the critical choices we face. s I said earlier, I approach the energy transi- n with guarded optimism. I am optimistic cause I see market forces both inducing nservation and increasing energy supplies. etroit is on a crash program to produce fuel ficient autos not because Washington re- ires them to, but because you and I—the nsumer—have required them to. Oil-drilling tes have set new records in the U.S. in 1980 part because of oil price deregulation. We e entrepreneurial activity all over the coun- y in developing and marketing conservation oducts and new energy alternatives. This es not mean that government policy is un- portant. Development of syn-fuels will not cur without government assistance—at least tially because the private risks are too great. so, weighing externalities and societal risks ainst private costs must be accomplished in e political arena. We as economists have a emendous educational role to play in this gard to convey the nature and importance of ese critical energy choices.

ferences

xon Corporation. *World Energy Outlook*. New York, 1980.

Ford Foundation. *Energy: The Next Twenty Years*. Cambridge, Mass.: Ballinger Publishing Co., 1979.

Lovins, Amory B. *Soft Energy Paths: Toward a Durable Peace*. Cambridge, Mass.: Ballinger Publishing Co., 1977.

Lonnroth, Mans, Peter Steen, and Thomas Johansson. *Energy in Transition: A Report on Energy Policy and Future Options*. Berkeley: University of California Press, 1980.

Meekhof, Ronald, Mohinder Gill, and Wallace Tyner. *Gasohol: Prospects and Implications*. Washington, D.C.: U.S. Department of Agriculture, ESCS, 1980.

Meekhof, Ronald, Wallace E. Tyner, and Forrest Holland. "U.S. Agricultural Policy and Gasohol: A Policy Simulation." *Amer. J. Agr. Econ.* 62(1980):408–15.

National Research Council, Committee on Nuclear and Alternative Energy Systems (CONAES). *Energy in Transition 1985–2010*. San Francisco: W.H. Freeman & Co., 1979.

———. *U.S. Energy Supply Prospects to 2010*. Washington, D.C.: National Academy of Sciences, 1979.

Resources for the Future, National Energy Strategies Project. *Energy in America's Future: The Choices Before Us*. Baltimore, Md.: Johns Hopkins University Press, 1979.

Southey's Colloquies on Society (January 1830). *Critical and Historical Essays Contributed to the Edinburgh Review*, Lord Macaulay, vol. 1, pp. 215–66 (at pp. 265–66). London: Longmans, Green and Co., 1890.

Stobaugh, R., and Daniel Yergin, eds. *Energy Future: Report of Energy Project at the Harvard Business School*. New York: Random House, 1979.

U.S. Congress, Office of Technology Assessment. *An Assessment of Oil Shale Technologies*. Washington, D.C., 1980.

———. *The Direct Use of Coal.* Washington, D.C., 1979.

———. *Energy from Biological Processes.* Washington, D.C., 1980.

U.S. Department of Energy. *Quarterly Report (Fourth Quarter 1979): Energy Information.* Washington, D.C., Apr. 1980.

Workshop on Alternative Energy Strategies (WAES). *Energy: Global Prospects 1985–2000.* New Yo McGraw-Hill Book Co., 1977.

World Coal Study (WOCOL). *Coal: Bridge to the Futu* Cambridge, Mass.: Ballinger Publishing Co., 198

———. *Future Coal Prospects: Country and Regior Assessments.* Cambridge, Mass.: Ballinger Publis ing Co., 1980.

Economic Feasibility of Agricultural Alcohol Production within A Biomass System

Donald Hertzmark, Silvio Flaim, Daryll Ray, and Greg Parvin

From 1980 to 1990, the United States will face . situation of continuous decline in domestic production of petroleum from conventional ources. At the same time that our depenlence on imported oil becomes more severe, he use of lead and other octane boosters that ubstitute for energy and feedstock in the reining of oil will diminish to zero. Fossil-based ynthetic fuels are a likely alternative—but nly in the long term, beyond 1990. For the ext ten years, ethanol will be the only synhetic fuel commercially available in sigificant quantities. Moreover, the likelihood hat a large portion of coal-based synthetic uels will be alcohols or low octane gasolines nakes ethanol a compatible component of the ation's fuel system for the foreseeable future. This paper discusses technical and economic easibility, energy requirements, product ecoomics, and policy issues of producing ethanol rom renewable sources.

Technical and Economic Feasibility

The two major technical features of the production of fuel ethanol from grains and sugars re the grain handling and the actual fermentaion and distillation of the fermentable sugars. n the beverage process, the entire grain is ent through the cooking and fermentation cyle. The residue that comes from the distillaion columns is a fibrous (7%–8%), highrotein animal feed, distillers' grains. The bevrage technique is a fixed proportions proess yielding about 2.5 gallons of "dry" thanol and 16.8 pounds of distillers' grains 26%–30% protein) per bushel of grain input.[1]

The major alternative to the beverage process is the wet milling of corn for the production of oil, meal, feed, and fermentable sugars. This technique yields 2.5 gallons of dry ethanol, 1.7 pounds of corn oil, 11.2 pounds of gluten feed (22% protein), and 3.3 pounds of gluten meal (62% protein) per bushel of corn input (Keim). From a technical standpoint, the wet milling has several advantages vis-à-vis the beverage technique. First, less total volume is sent through the distillation columns, so that the columns may be smaller per unit of ethanol output. Second, the grain-handling and ethanol production parts of the facility are largely separate, so that innovations in either part of the technology can be adopted without a disruption of the rest of the process. And finally, the joint products of the wet milling approach have a greater economic value than the beverage byproduct due to the lower fiber content of the joint feed products compared to distillers' grain.

Both the beverage and wet milling techniques can use either batch or continuous fementation. Distillation can be either at atmospheric pressure or under vacuum. Continuous fermentation reduces fermentation time from approximately forty-eight hours to about eight hours (Chemapec) and lessens capital investment costs. Vacuum distillation produces 199^{+} proof alcohol in the distillation column at 120°F, thereby lowering steam requirements greatly. Most assessments of the energy, capital, and material requirements for ethanol production have been based on the least desirable set of production techniques. That is, the beverage process is assumed with distillation at atmospheric pressure and fermentation of the grain in batch rather in a continuous process.

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[1] Water may be left in the alcohol if it is to be used straight or njected into the engine from a separate tank. Conventional distilation can produce only 95% ("neat") alcohol. Removal of the additional water requires benzene or gasoline distillation or one of several techniques such as selective membranes and molecular sieves.

Non-Feedstock Production Costs and Energy Requirements

Table 1 gives the production costs of alternative technologies. The estimated costs of production appear to converge about 70¢–85¢ per gallon, with lowest values reported by Lawrence Berkeley Laboratories (Maiorella, Blanch, Wilke) and the highest by the Department of Energy and Litterman, Eidman, and Jensen. The Chemapec and the Berkeley processes are extremely energy efficient so their variable cost components are relatively immune to increases in energy costs.

The advanced technologies being developed at the Lawrence Berkeley Laboratories include such improvements on the vacuum distillation and continuous fermentation techniques as flash fermentation and cell recycle. These technologies represent significant advances over existing low energy techniques.

Engineers from the Solar Energy Research Institute have performed an engineering and economic evaluation of an existing farm still in southeast Colorado and have found that the still compares favorably to existing beverage distilleries on both cost and energy bases (Jantzen and McKinnon).

As is evident from table 1, energy consumption is substantially higher for the traditional beverage processes (Keim; Litterman, Eidman, Jensen) compared to advanced or energy conserving processes (Office of Technical Assessment, Chemapec wet milling, Berkeley Lab, and Solar Energy Research Institute). Beverage distilleries for manufacturing ethanol are generally fueled by either natural gas or heating oil (no. 2). A few existing distilleries are fueled by coal or residual oil (no. 6). In almost all cases, these plants consume a significantly greater amount of fuel than is contained in the ethanol that is produced. Using these data, some analysts have concluded that alcohol fuels are merely a means of transforming natural gas or heating oil into an alternative form of high grade fuel. Cogeneration and use of waste materials to satisfy heat requirements provide alternative energy sources which are not reflected in cost or energy requirements in table 1.

The use of steam from power plants or other large energy sources is feasible for the entire ethanol production process except for mechanical drive needs. Using this low-grade energy to assist in producing high-grade energy could result in the net use of 3,000 to 22,000 Btu for the beverage process and 5,000 to 12,000 Btu for the wet-milling system.[2] Even adding energy consumption for growing the corn (36,000 to 72,000 Btu) co-generation of energy would show a favorable effiency ratio, especially since ethanol could provide the equivalent of 100,000 Btu per gallon due to higher combustion efficiency when mixed with lower octane gasoline. Ethanol distilleries have been proposed that would use waste steam of oil refineries (Commerce City, Colo.) or low-grade steam of geothermal reservoirs (Grand Junction, Colo.). Such efficiency compares well to finished fossil products since they must contain strictly less energy than was removed from the earth.[3]

Fossil energy requirements of ethanol production can also be reduced substantially by using waste materials for process heat requirements. Potential feedstocks include forest product, agricultural, and municipal solid wastes. Agricultural materials suitable for supporting an ethanol facility include animal manure from confined operations, food processing and packing wastes, and crop residues. The most advanced conversion technologies for using these materials include anaerobic digestion, gasification, and direct combustion (JG Press, English et al., Levelton & Assoc., Junge). Direct combustion is a low-cost application with many systems commercially available. Capital costs for bale burners are as low as $6,000 for systems in the 5 to 6 MBtu per hour size range (Flaim and Urban).

The principal advantage of agricultural waste materials is low feedstock costs. Propane at 65¢ per gallon (91,000 Btu/gal.) costs approximately $7.10/MBtu, while on-farm collection costs estimates of crop residue range from $8.00/ton (13 MBtu/T.), or 62¢/MBtu (English et al.) to about $16.00/ton or $1.25/MBtu (Duave and Flaim). Costs for residues transported ten miles range from $20 to $30 per ton ($1.50 to $2.30 per MBtu).[4]

At the present time, there are no commercial technologies for the fermentation of lig

[2] These figures are obtained by assuming that premium energ[y] need be used only for mechanical drive and that heat requirement[s] are met from coal or renewable sources. Details may be obtaine[d] from the senior author.

[3] Amidst all the furor over energy use for alcohol production, [it] is generally forgotten that the petroleum-refining industry is th[e] largest industrial gas user.

[4] A good summary of wood waste combustion systems suitabl[e] for direct combustion of crop residues is contained in Levelto[n]. The limitations of using wood waste materials for direct combus[-]tion is reviewed by Junge.

Table 1. Costs of Selected Technologies for Ethanol—Estimates from Recent Studies Net of Feedstock Costs ($19.80/Gallon of 99.8% Ethanol)

Study[a]	OTA(1979)[c,d]	Keim (1979)[c]		Chemapec[f]	Litterman, et al. (1978)[c,e]	DOE(1979)[c,d]	Berkeley Maiorella et al		SERI[c]
type	beverage	wet-milling	beverage	wet-milling	beverage	beverage	beverage[c,d]	advanced[f]	farm
Costs[b]									
Variable	.08–.17	.40	.40	.18	—	.25–.32	—	—	.28
Fixed[g]	.55	.44	.32	.57	—	.45–.68	—	—	.55
Total	.63–.72	.84	.72	.75	.78–.93	.70–1.00	.58	.35–.46	.83
Processing Energy[j] (Btu/gal)	34,000	93,000	108,000	24,000	108,000–175,000	Not available	47,000 (36,000)[i]	25,000 (14,000)[i]	29,000

[a] All studies assuming grain feedstock except Berkeley study (see note [i] below).
[b] All studies used different accounting conventions. In general, variable costs included fuel and enzymes; fixed costs included capital charges, depreciation, maintenance, labor, and profit.
[c] Batch fermentation and atmospheric distillation.
[d] Energy-conserving distillation.
[e] Collected from several studies.
[f] Flash fermentation, vacuum distillation. A similar, though less advanced process, is currently available commercially.
[g] Based on 20% rate of return on invested capital.
[h] A gallon of ethanol contained 85,000 Btu.
[i] Lower figure is for cellulose feedstocks, higher figure is for grain.
[j] Includes drying of stillage except for SERI farm-still study.

nocellulose (wood and agricultural residues). For these feedstocks, gasification and methanol synthesis is the far more likely route to alcohol fuels than is fermentation with existing technology. For manures and similar organic wastes, anaerobic digestion to methane for possible conversion to either methanol or electricity is the likely means of energy conversion.

Corn Feedstock Economics

The impacts of using corn to produce ethanol fuel on the agricultural sector of the U.S. economy were simulated with a national agricultural policy simulator (POLYSIM). The model contains supply and demand relationships for the major U.S. crop and livestock categories. For the purposes of this analysis, several modifications were made to POLYSIM. A series of equations was estimated to determine the domestic demand for the gluten meal and distillers' grains and the interactions of these demands with other grains and concentrates. Further work is in progress to include export relationships for the byproducts and to integrate the corn, soybean, and cottonseed oil sectors into the analysis. Linear growth in alcohol production was imposed on the model over a five-year period, with final year production ranging from 200 million gallons per year (80 million bushels of corn) to 1 billion per year (400 million bushels of corn).[5] An even split between processes generating dried distillers' grains and gluten feed and meal was assumed.

The preliminary results are summarized in table 2. In the final year of the five-year simulation period, corn prices and acreage increase and soybean acreage decreases slightly, but in general the impacts on the corn and soybean sectors are nominal. Final-year prices for gluten feed, distillers dried grains, and soybean meal for the 1 billion gallon alternative decrease by 26%, 28%, and 7%, respectively. Final-year soybean prices are nearly constant, with reduced supplies offsetting the effects of lower meal prices. However, not accounting for the effects of increased corn oil, production on the vegetable oil market biases soybean prices upward.

Soybean meal exports increase and the value of corn exports also increases. Overall, export earnings increase slightly with the

[5] A 3 billion gallon scenario was simulated. However, the joint produce demand equations contained no export provision. As a result, the joint product prices went below their values as boiler fuels. Simulation of more ambitious levels of ethanol production will need to include export oil joint products.

Table 2. Price Effects of Alternative Ethanol Programs on Selected Agricultural Sector Variables, 1979–83

			1983 Production (million gal./yr.)		
Variable	1979 Baseline	1983 Baseline	200	500	1,000
Corn					
Price ($/bu.)	2.48	2.47	2.50	2.53	2.59
Acreage (m.ac.)	69.63	75.88	75.99	76.16	76.45
Exports (m.bu.)	2,500.00	2,300.00	2,286.80	2,266.91	2,233.73
Soybeans					
Price ($/bu.)	6.76	7.05	7.06	7.07	7.08
Acreage (m.ac.)	73.42	67.54	67.44	67.28	67.04
Exports (m.bu.)	1,025.00	900.00	899.52	898.72	897.66
Gluten metal ($/ton)	110.26	119.41	113.32	103.78	87.79
Distillers' grains ($/ton)	122.62	132.80	125.68	114.50	95.79
Soybean meal					
Price ($/ton)	185.06	200.42	197.74	193.74	187.01
Exports (thou. tons)	6,298.95	6,627.94	6,687.26	6,775.37	6,923.57
Export earnings					
Corn (M$)	6,200.00	5,681.00	5,717.00	5,737.28	5,785.36
Soybeans (M$)	8,094.67	7,673.37	7.672.95	7,666.61	7,650.21
Total (M$)	14,294.67	13,354.37	13,389.95	13,401.89	13,435.57
Government payments (M$)	1,727.47	1,481.87	1,479.31	1,475.93	1,469.86
Net farm income (M$)	31,890.25	32,732.63	33,020.63	33,456.94	34,201.94

Source: POLYSIM; Hertzmark, Ray, Parvin.

ethanol programs. The U.S. balance of trade n agricultural commodities appears to be little ffected by the production of ethanol in the ear term. Net farm income increases only noderately with ethanol production of up to 1 illion gallons by the end of five years.

Sugar Crops

The fermentation of sugar crops such as cane, eets, and sweet sorghum represents an addiional potential for fuel ethanol production. The same facilities that process grains can be sed for sugar crops with some relatively ninor modifications of the front end of the lant. With the exception of the sugar beet, one of these crops produces a joint product or food or feed use, though sugar cane distileries are in general net producers of energy electricity and steam) because of the trenendous volume of bagasse that is produced long with the cane (Adams). The less sophisicated processing vis-à-vis grains and celulose permits lower expenditures on the capial side; however the net cost of production is pproximately the same because of the lack of narketable joint products.

Table 3 presents the net costs of producing thanol under the range of conversion costs iven in table 1 and the feedstock and joint production costs given in table 2. For comparison, it is necessary to know the marginal cost of gasoline. To determine the marginal cost of gasoline, one must distinguish between domestic and imported supplies of crude oil. Domestic crude oil prices vary widely because of federal regulations on its definitions of "old" and "new" oil. Uncontrolled domestic oil is selling for more than $40 per barrel while oil subject to price controls is less than one-third this price (*Oil and Gas Journal*, p. 158). The most expensive imported crude based on posted prices comes from Libya and Algeria, with prices of $36.72 and $34.21 per barrel, respectively. In addition, Algeria charges a $3.00 per barrel exploration fee (*Oil and Gas Journal*). Foreign prices are f.o.b. port of loading and exclude transoceanic shipment and handling charges. At the posted price of Libyan crude, the cost of feedstock for gasoline is at minimum $0.874 per gallon ($36.72 ÷ 42 gal./bbl. = 0.874) excluding transoceanic shipment, handling, and refining costs.[6] These latter charges have been esti-

[6] The naphtha and other light fractions that are refined to gasoline and petrochemicals are more valuable than the heavier fractions. Only one OPEC member, Venezuela, exports naphtha for gasoline rather than crude. Recent prices for Venezuelan naphtha have been about $39–40/bbl (90¢–95¢ per gallon of gasoline). This would increase refinery gate and retail prices to $1.50 and $1.77 per gallon, respectively.

able 3. Costs of Ethanol Production under Alternative Scenarios (in Dollars per Gallon)

	1983 Production (Million Gallons/Year)[a]			1980 Actual (Mid-May Prices)[b]
em	200	500	1,000	
orn	1.00	1.01	1.01	0.98
redits				
Distillers' grains	.42	.39	.32	.34
Gluten meal and feed	.41	.39	.37	.36
Corn oil	.21	.21	.21	.15
et feedstock costs				
Beverage	.58	.61	.68	.64
Wet-milling	.38	.40	.42	.47
ermentation and distillation				
Beverage		.58–1.00		
Wet-milling		.75–.84		
otal				
Beverage[c]	1.16–1.58	1.19–1.61	1.26–1.68	1.22–1.64
Wet-milling	1.13–1.22	1.15–1.24	1.17–1.26	1.22–1.31
Marginal gasoline (refinery gate)				1.22–1.31
	-------------	-1.46-	-------------	

Calculated for previous tables.
Farm price for corn.
Tyner's prices for ethanol range from $0.93–1.63/gallon but assume 15% r.o.i. instead of the 20% assumed above (Tyner, p. 15).

mated to be about $24.50 ($1980) per barrel (Flaim and Mount) excluding refinery losses. These average cost estimates combined with feedstock charges make the lowest possible cost for unleaded gasoline from Libyan crude $1.45 per gallon at the refinery gate. This implies a marginal retail price approaching $1.72 per gallon.

For all production scenarios, the price of ethanol is generally below that of marginal gasoline cost. Wholesale prices for wet milling process alcohol are in fact substantially less than for marginal gasoline at the refinery gate. Even with low value joint products as in the 1 billion gallon scenario, ethanol is competitive with marginal gasoline. For the beverage process, the implications are not as sanguine. The generally lower value of joint product and the high capital and energy costs make this technique less attractive for large-scale production compared to the wet milling process. Use of co-generation or waste materials as fuel sources would further enhance ethanol's price competitiveness with gasoline.

Policy Implications

Given the tax exemptions, loan guarantees, and tax credits either enacted under existing legislation or in pending legislation, gasohol development already has received considerable public policy attention. Well-meaning government actions—taken too far—can be inferior to a policy of standing back and letting market forces work. Of course, society has the prerogative of using subsidies to augment private economic incentives to countervail perceived external diseconomies of importing large quantities of oil. External diseconomies of gasohol production, such as increased soil erosion from adding marginal cropland and mining soil due to residue collection for fueling alcohol plants, also require consideration, however. Present and probable future increases in world crude oil prices and current improvements in alcohol production techniques could well justify future investments in alcohol plants without direct government subsidies. Rather than biasing resource use by providing tax exemptions or other subsidies for a specific syn-fuel (alcohol), the government could facilitate syn-fuel research and bear a portion of the risk through loan guarantees; perhaps acting as a demander of last resort.

Crash programs such as promoting and providing incentives for the construction of "a still on every farm" will probably do just that—crash. Farmers who have the grain for alcohol feedstock and the livestock for feeding the byproducts generally do not have the time nor technical expertise to run an alcohol plant seven days a week the year around.

Government farm programs will need to be modified to reflect the use of farm commodities for alcohol feedstocks. In particular, grain reserve targets and acreage diversion programs will need to be managed to accommodate the grain requirements of ethanol plants on an equal basis with grain needs of other consumers and users of grain. Loan rates, target prices, and procurement prices would be nondiscriminatory with respect to the end use of grain.

References

Adams, R. "Agricultural Adjustments to Brazil's Alcohol Program—A Regional Analysis." Ph.D thesis, Ohio State University, 1979.

Chemapec, Inc. *Industrial Alcohol by Continuous Fermentation and Vacuum Distillation*. New York, 1979

Dauve, Jan, and Silvio J. Flaim. *Agricultural Crop Residue Collection Costs*. Golden, Colo.; Solar Energy Research Institute SERI/RR-353-354, Dec. 1979.

English, Burton C., et al. *Economic Feasibility of Using Crop Residues to generate Electricity in Iowa*. CARD Rep. No. 88, Iowa State University Jan. 1980.

Flaim, Silvio, and T.D. Mount. *Federal Income Taxation of the United States Petroleum Industry and the Depletion of Domestic Reserves*. Golden, Colo.: Solar Energy Research Institute SERI/TR-52-041, Oct 1978.

Flaim, Silvio J. *Soil Fertility and Soil Loss Constraints on Crop Residue Removal for Energy Production*. Golden, Colo.: Solar Energy Research Institute SERI/RR-52-324, Jul. 1979.

Flaim, Silvio J., and David Urban, *The Costs of Using Crop Residues in Direct Combustion Applications*. Golden, Colo.: Solar Energy Research Institute SERI/TR-353-513, Mar. 1980.

Hertzmark, D., and B. Gould. *The Market for Ethanol Feed Joint Products, Solar Energy Research Institute*. Golden, Colo.: Solar Energy Research Institute #TR 352–357, 1979.

Hertzmark, D., D. Ray, and G. Parvin *The Agricultural Sector Impacts of Making Ethanol from Grain, Solar Energy Research Institute*. Golden, Colo.: Solar Energy Research Institute #TR-352-554, 1980.

Jantzen, D., and T. McKinnon. *Preliminary Energy Balance and Economics of a Farm-Scale Ethanol Plant*. Golden, Colo.: Solar Energy Research Institute 1980.

J. G. Press. *Biogas and Alcohol Fuels Production*. Emmaus, Pa., Jan. 1980.

Junge, David C. *Boilers Fired with Wood and Bark Residues*. RB No. 17, Oregon State University, Nov. 1975.

Keim, Carroll R. "Economics of Ethanol and D-Glucose Derived from Corn." American Chemical Society Proceedings, May 1979.

Levelton & Assoc. *An Evaluation of Wood Waste Energy Conversion Systems*. Vancouver, B.C., Mar. 1978.

Litterman, M., V. Eidman, and H., Jensen. *Economics of Gasohol*. Econ. Rep. ER 78-10, University of Minnesota, 1978.

Maiorella, B., H., Blanch, and C. R. Wilke. *Rapid Ethanol Production via Fermentation*. AICLE, Nov. 1979.

Office of Technology Assessment. *Gasohol: A Technical Memorandum*. Washington, D.C., 1979.

Oil and Gas Journal, 26 May 1980.

Tyner, W. *The Potential Using Biomass for Energy in the United States*. Purdue University, May 1980.

U.S. Department of Energy. *The Report of the Alcohol Fuels Policy Review*. Washington, D.C., 1979.

Ward, G., and J. Matsushita. *Feeding Value of Distillers' Dried Grains (DDG) in Beef Feedlot Rations*. Dep. Animal Sci., Colorado State University, 1980.

Energy and the Structure of Agriculture: A Political Economic Analysis

David Holland

The purpose of this paper is to provide an analysis of how the "energy crisis" is likely to influence the direction of future U.S. agricultural development. Emphasis will be placed on examining the main forces that will influence change in organizational type and size distribution of farm units.

In the view of neoclassical economic theory, the structure of an industry ultimately derives from the interaction between competitive market forces, relative price ratios, and a number of quasi-exogenous elements such as economies of scale, available technology, possible government regulations, and time lags in adjustment. From this perspective, the structure of agriculture is simply the outcome of a number of largely independent forces regulated in the public interest through the market. In the model developed in this paper, such a view represents a case of misplaced emphasis, incapable of generating a clear understanding of the principal mechanisms affecting structural change.

A Model of Structural Change in Agriculture

While market forces undoubtedly have an influence on the size distribution of farms at any given time, other forces reflecting essentially underlying distributions of wealth and political power are the more important determinants. To understand the dynamics of structural change in agriculture and the possible impact of energy shortage, the role of the state and role of asset distribution in agriculture must first be discussed.

The Role of the State

Economic activities in America may be classified into two broad categories: activities organized by private capital and those organized by the state (O'Conner). Production and distribution in the private sector falls into two subgroups: competitive industries organized by small business and monopolistic industries organized by large-scale capital (O'Conner).

In the competitive sector, production is typically small scale and markets tend to be regional or local in scope. Capital requirements are low and there is a tendency toward overcrowding. Output per worker is low and wages are low. Competitive sector wages, prices and profits are determined mainly by marke forces. Farming may be seen as a once competitive industry rapidly on its way to los ing its competitive character.

The monopoly sector is characterized by large-scale production. Barriers to entry ar plentiful. In the monopoly sector, marke forces are not the main determinants of wages prices, and profits. Monopolistic corporation have substantial economic power and are abl to administer prices. Wages are determined b worker productivity and the bargaining powe of unionized workers.

The role of the state in this economic syster is to carry out two main functions: accumula tion and legitimization. First, it must assure a economic environment conducive to expar sion of business activity and the accumulatio of capital both at home and abroad. Seconc the state must try to maintain or create cond tions for social harmony. Examples of the fir type of activity are fiscal and monetary polic foreign policy, education and manpower po icy, and investment in physical capital pro ects providing basic infrastructure, such a freeways, airports, and mass transit system Examples of the second type of activity ai insurance against sickness, old age, unen

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ployment, public housing, and, in short, much of what is now known as the "welfare" activities of the state.

The character and policies of the state derive from its legitimization and accumulation functions as the state attempts to resolve the various contradictions introduced by the growing importance of the monopoly sectors. It is not necessary to explore these contradictions in this paper, as they have been well-developed elsewhere (O'Conner). What is important for our purposes is to recognize that behavior of the state is going to be influenced mainly by the needs of the large monopoly sectors of the economy. To the degree that broad national policies are developed that affect farming, the well-being of most farmers will be an incidental consideration.

The Role of the Distribution of Land and Capital in Agriculture

The existing distribution of wealth in farming deserves special attention in our discussion because it is the main determinant of class structure in most rural areas (Gotsch) and class interests. In any rural area in the U.S., some variation of the following structure can be found. At the top of the pyramid are large businesses, large industrial-type farms, and larger-than-family-type farms (Rodefeld). Owners of these resources may reside in the area, but often do not. Next come the small capital owners who provide most of their own labor and management. Examples are family-type farms and small business. Finally there is the great majority of the propertyless, who do not own productive assets and who exist largely through the sale of their own labor.

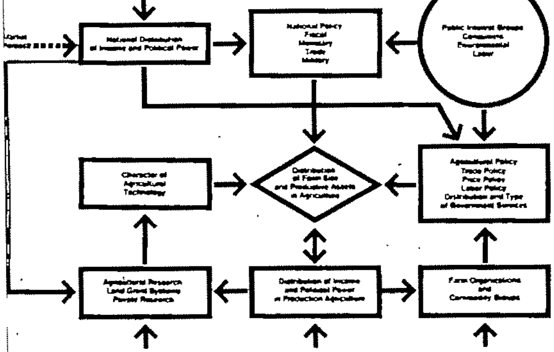

Figure 1. Flow diagram of factors affecting the distribution of farm size in U.S. agriculture

Agricultural development inevitably changes the welfare of each group, and each group desires to influence that development in ways that are beneficial to them. The two main areas in which the distribution of personal income and political power are hypothesized to influence future agricultural development are through the character of technological change in agriculture and the character of overall agricultural policy viewed as not only formal policy legislation, but also as government regulation and the type and orientation of governmental agencies that are supposed to serve agriculture.

Various Components of the System and Their Feedback Effects

A formal model of the determinants of agricultural structural change is presented in figure 1. The distribution and magnitude of personal income and political power in the farming sector (represented in the diamond) is the central element influencing structural change. The distribution of income and power is determined mainly by the distribution of land and capital in farming and the stage of historical development in agriculture. Because large components of farming are still competitive, market forces also have some influence upon agricultural income. Income levels and the resulting political power then become the inputs into the three main feedback loops influencing agricultural structure: capital accumulation, technological change, and agricultural policy.

The character of agricultural technology is viewed as influenced by the type of agricultural research done. To some degree that research will be directed by present and expected future relative price ratios as the induced development hypothesis (Hayami and Rüttan) would suggest. But of greater importance is the issue of who is allowed to define the important problems. Agribusiness, which in figure 1 is treated as in the rest of the economy, and the larger farmer's interests are the most important here. Since the research perspectives of each of these groups are dominated by the large concentrations of capital represented, the problems defined are those of the large agribusiness firms and the largest farmers. Consequently, technological change is focused upon solving those particular problems. As a result much of the research that is done is most appropriate for very large farms.

Even when technology is divisible across farm size, savings to acquire new land and capital will be generated mainly from the profits of larger farmers and agribusiness firms, and pressure for the expansion of farm size can be expected to continue from these sources. It is savings generated from both the absolute magnitude and distribution of farm income which provide the second main feedback loop affecting farm size (denoted by the double arrow between income distribution and asset distribution).

The third feedback loop relates farm income and political influence to the character of the institutions serving agriculture and to farm policy. The current beneficiaries of government services, who are mainly the larger farmers, do not want to see their control of these services passed over to other individuals. Agricultural development in directions that seem to threaten this control will be strongly resisted. To the degree that existing farmers and commodity groups are able to influence policy, the policy that emerges will serve existing holders of agricultural capital and will help to further consolidate the concentration of this capital.

The ability of agriculture to influence only partially the determinates of its own structural change is emphasized by the role ascribed to the national distribution of income and political power. Here competitive market forces have minor influence (indicated by the dotted arrow), with most impact deriving mainly from the underlying distribution of wealth at the national level. This distribution of income and political power guides the activities of the state as it acts in either its legitimization or accumulation aspects. Fiscal, monetary, trade, and military policy at the national level affect both the size and distribution of income in farming which, in turn, directly and indirectly influence the size distribution of farms.

The national distribution of income and political power will also, as indicated in figure 1, have a direct effect upon both the character of agricultural policy and technological change. Inasmuch as the more advanced monopolistic sectors are able to wield more political power, it is not unreasonable to expect agricultural policy and research directions to develop which are conducive to the extraction of large profits from the farming sector by agribusiness corporations.

Finally, the role of the special interest groups associated with the consumer, labor, and environmental movements must be considered. Such groups are largely outside of the main flows of economic and political power in this country and are depicted as such in figure 1. Nevertheless, such groups are viewed as having an influence on both national, and more specifically, agricultural policy, decisions.

Implications of Energy Shortage for Structural Change in Agriculture

Within the framework described in figure 1, it is now possible to return to the issue of the likely impact of energy scarcity on the size distribution of farms. In periods of petroleum shortage it has become clear that a reoccurring problem of advanced industrial economies is the addition of energy-induced inflationary pressures to other inflationary sources as increased energy costs pass through the industrial system (Carter and Youde). In an attempt to fight both inflation and balance of payments problems, anti-inflationary fiscal and monetary policy is pursued resulting in the now all too familiar characteristic of the 1970s—stagflation.

With stagflation as the overall economic picture for the 1980s, the forecast for agriculture that I see is one of an increasingly severe cost-price squeeze. Energy will be allowed to continue to rise in price, while simultaneously the price of wage goods will be held down to the degree possible with a cheap food policy. Lowered rates of economic growth around the world will lead to a lowered rate of growth for U.S. agricultural exports.

Within this general picture there will be attempts to ameliorate the impact of energy price increases through short and long-run technological change and government assistance. All such possible policy programs and research development must first, however, be filtered through the lens of economic class interest. Because existing research and policy institutions are heavily dominated by large industrial-type farm (Rodefeld) interests, it is not likely that the emerging research and policy directions will be directed toward improving the survival chances of smaller and medium-sized farms or the well-being of agricultural labor. An example of this sort of selectivity can be found in a recent work where "realistic and unrealistic" responses to energy shortages are discussed (Buffington and Zar).

Conclusions

Assuming the preceding analysis is correct, the future for the family-type farming in America is bleak indeed. Faced with an intense cost-price squeeze arising to some considerable degree from energy scarcity and the nature of agricultural input and output markets, family-type farms are unlikely to witness the specific kind of research development or government programs that will permit or enhance their viability.

The many contradictions including the energy crisis that now beset agriculture demand that the issue of structural change be treated as a possible policy variable rather than as an exogenous constraint. The goals of an ecologically sound and socially equitable agriculture will require that the agricultural treadmill be stopped. This will necessitate that the role of so-called "competitive market forces" be lessened or eliminated with greater emphasis upon social planning and social control of the food system. Such an accomplishment will in turn require reorientation of research in the land-grant system toward greater emphasis on energy conservation, environmental soundness, and social equity aspects of technological change. The other public institutions supposedly serving agriculture will have to be similarly directed.

While some will argue that the present direction of change is in similar directions, it must be emphasized that change is taking place only within a context that is circumscribed by the class interests of existing concentrations of land and capital. To attempt to make adjustments to energy shortage strictly within the confines of the existing agricultural structure will be very detrimental to family-type farms and eventually to the democratic principles upon which this country was founded.

The type of policy, research, and economic redirection just discussed will not materialize out of thin air. Strong shifts in political alliances will be required. The large number of currently existing family-type farms will have to realize that they are not being well served by the existing set of institutions. They must recognize their endangered position and realize that their present identification and alliance with the interests of large-scale industrialized farming eventually will lead to the extinction of both their living and way of life.

A new political alliance must be forged; not with the agribusiness elite but with the progressive elements of labor, consumer, environmental, and women's groups. Traditionally, these groups have been viewed as enemies of agriculture. What existing family-type farmers are going to have to realize is that agriculture's erstwhile friends have the family farm locked in a death grip and that the only hope for survival lies in breaking the stranglehold.

References

Buffington, J. D., and J. H. Zar. "Realistic and Unrealistic Energy Conservational Potential in Agriculture." *Agriculture and Energy*, ed. William Lockertz, pp. 695–712. New York: Academic Press, 1977.

Carter, Harold O., and James G. Youde. "Some Impacts of the Changing Energy Situation in U.S. Agriculture." *Amer. J. Agr. Econ.* 56(1974):878–88.

Gotsch, Carl H. "Technical Change and the Distribution of Income." *Amer. J. Agr. Econ.* 54(1972):326–41.

Hayami, Yujiro, and Vernon Ruttan. *Agricultural Development: An International Perspective*. Baltimore, Md.: Johns Hopkins University Press, 1971.

O'Conner, James. *The Fiscal Crisis of the State*. New York: St. Martin's Press, 1973.

Critical Choices in Energy: Discussion

Norman Rask

The energy problem has been recognized for several years. Yet, our profession has delayed in making serious efforts to identify and address energy realities. Part of this reluctance stems from an inability to see clearly our energy future. It is generally recognized, however, that we have reached a turning point. A long history of declining relative energy costs and a perceived abundance of oil has been reversed. Now, new sources of energy and new energy use patterns must be developed. Past experience is of limited value in determining the environment within which these critical choices in energy are to be made. It is difficult, for example, to make demand projections without a valid historical base. The relationship between economic growth and energy use, as well as the degree of conservation that can be expected in the future, is relatively unknown. In addition, there are many uncertainties on the supply side, such as the future Irans, Mexicos, Three Mile Islands, and development of new technologies. These are all situations that will alter the conditions as we now see them and, thus, affect our future choices in energy. Within this difficult framework, our panel has made important contributions. In the following discussion, I identify some of these major contributions, suggest some additional points I would have liked to see addressed, and outline a general framework for further study.

The Tyner paper makes a particularly important contribution in presenting a balanced view of the energy transition from the 1980 perspective. I believe the general direction, timing, and magnitude of the energy transition that is depicted is essentially correct. With the excellent frame of reference provided, one is tempted to ask for much more. I would have liked, for example, to see more attention to world versus U.S. situations relative to supply, demand, and price possibilities. It would have been helpful to have some projections on future levels of petroleum prices. For example, will coal liquids, oil shale, and alcohol put an effective price ceiling on petroleum? If so, are we looking at a doubling of 1980 oil prices in real terms over the next ten years, or as Tyner has suggested, will production limits imposed by environmental factors, costs, and water availability restrict production of these alternative liquid fuels to the point that they cannot provide an effective brake on petroleum prices?

A reference to the unique U.S. energy resource base would have been helpful since most other countries of the world face a somewhat different energy transition. Brazil, for example, which imports over 80% of its petroleum requirements and has a large underutilized land base is moving rapidly toward a significant substitution of alcohol for its liquid fuel needs. Brazil also will utilize a significant hydroelectric potential. France, on the other hand, with scarce domestic energy resources, is moving toward a much heavier reliance on nuclear energy. These are two examples that illustrate how individual countries facing different energy and agricultural resource situations will find substantially different paths through the energy transition.

The Hertzmark and Flaim paper is complementary to the Tyner paper. It deals more specifically with agriculture's contribution to meeting petroleum shortages over the next decade. There are two important points in this paper. First, it highlights the fact that biomass alcohol will serve two purposes. It will be both a substitute liquid fuel before the more plentiful synthetic fuels can be produced in significant quantities and also a useful additive to those fuels when they become available. Second, their review of changing alcohol production technology demonstrates that new developments are bringing about substantial improvements in processing technology and energy balances in a short time. I would have liked to see a broader treatment of the food-feed-fuel issue. Simulations were run over too narrow an alcohol production range and too

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short a time horizon to get at the commodity price and land use questions that certainly will arise as we move into a more substantial alcohol program. For example, had the alcohol production levels been extended to five billion gallons annually over a ten-year horizon, the authors may have come to substantially different conclusions concerning the impact on commodity prices.

The Holland paper looks at the potential structural changes in agriculture that will result from higher energy prices. This paper argues that the market power and political influence of large farm units will continue to increase at the expense of small farms as energy costs rise. The resulting inflation and cost-price squeeze will be more detrimental, in Holland's view, to the smaller farmers.

I have two problems with this characterization of the energy impact on agriculture. First, it puts too much of the structure burden on potential income impacts of rising energy costs. The structure question is a much broader issue. Second, as noted above, agriculture is in the unique position of being a supplier of energy, as well. Thus, the cost argument alone misses the positive income effects of alcohol production. In my view these positive income effects likely will outweigh in the aggregate the cost effects of higher energy prices. Certainly there will be some regional differences due to increased transportation, irrigation, and other energy input costs, but agriculture in general should prosper during the next decade.

I turn now to some general interpretations. There are at least three energy realities that will be important for agriculture and for researchers attempting to project the impact of the energy situation on agriculture. The first is that oil and natural gas will be important sources of energy for most planning horizons. Clearly they will be more costly, perhaps as much as \$50–\$60 per barrel at 1980 price levels. This projection has to be conditioned on many unknowns including the degree of conservation that can be obtained in the use of liquid fuels, and the relative quantities of coal liquids, shale oil, and alcohol that can be produced within the constraints mentioned earlier.

A second energy reality is that no new dominant energy source is known or likely to emerge over the next twenty years. The transition period will consist of a composite of energy sources and, therefore, no options should be foreclosed as we attempt to find replacements for oil and natural gas.

The third energy reality is that during the 1980s conservation and alcohol production are the only liquid fuel substitutes that can be provided in significant quantities. Thus, rising oil prices, externality costs of imported oil, and development of new alcohol technologies will all combine to make a modest alcohol industry politically desirable and economically attractive. This has far ranging implications for agriculture. The degree to which alcohol will be called upon to substitute for oil depends on many unknowns including conservation efforts, the political stability of the oil exporting countries, and future petroleum prices.

These general energy realities as they impact on agriculture suggest several areas for research and extension efforts. First, there is a need for public information programs. We clearly need public understanding not only of the energy realities but of the options, the uncertainties, and the relevant policies that flow from these conditions. Most institutions, both private and public, have strong credibility problems in the energy area. Thus, the university has a unique role to play in providing this form of public information.

An important area of needed research is the changing structure of demand for farm products. Demand estimates are especially important for assessing the impact of an alcohol fuels program. The U.S. consumer has tremendous flexibility in adjusting expenditure patterns. The manner in which he adjusts to higher energy prices in both food versus nonfood items as well as the substitution between individual food items will be an important determinant of the demand for farm products. The level of international demand for U.S. farm products will depend on both the income effect on consumer choices in other countries as they adjust to higher energy prices and the supply effect as countries such as Brazil shift to energy crops. This will affect local production of food and feed crops as well as the amount of agricultural products moving in international trade. Because the U.S. is also a major importer of agricultural products, these changes in other countries will affect both our imports and our exports.

Another research area relates to agricultural adjustments to higher energy prices. First, we need to incorporate energy costs explicitly in most research efforts. We have to use cost

sensitivity analysis over relevant energy price ranges, perhaps a doubling of real energy prices over the next ten years. As we look to specific forms of energy, there may be some differences. For example, if we consider marginal rather than average pricing of certain energy sources, a wider energy price range will be needed. This may be necessary also with energy sources that are now regulated and protected. The point is that any research effort that depends on the current price of energy for validity will have only very short-run usefulness.

A second research area under agricultural adjustments to higher energy prices is interregional competition. Transportation costs, energy use differentials by various agricultural enterprises, and the demand changes that will come about in specific regions with energy crop production are all factors that will affect interregional competitiveness. We need to anticipate what these changes will be.

Activities beyond the farmgate will be affected significantly by higher energy costs. Marketing, processing, and consumption activities actually use much more energy than farm production, and we need to study the impact of energy costs on each of these functions.

Energy crop production is the final general area of research emphasis. Many of the points mentioned earlier apply here as well. However, I think there are some specific issues that need special attention. First, with the interest and emphasis on small-scale alcohol production for on-farm uses, we need studies that look at incorporating energy production and consumption into the farm or the firm operation. Second, with rising energy prices and the existing subsidy program, we need to determine the level of subsidy or incentive policies that are needed. Finally, in line with the earlier demand studies, we need to determine the impact of energy crop production on the supply and price of our traditional farm commodities.

These are a few of the important areas that need immediate attention. It is a broad agenda and we have made only a very modest beginning.

Food Aid and Nutrition

John W. Mellor

Four questions should be considered when discussing improving human nutrition through food aid. What is the effect of increased food supplies and the corresponding decline in food prices on food consumption and the nutritional status of low income people? Can market interventions increase the efficiency of a given addition to food supplies for these purposes? What is the effect of reduced prices on food production? And, can market interventions decrease the unfavorable supply effects of consumption-oriented policies?

The two consumption questions address the issue of how to utilize a gross increase in food supply to improve quickly nutritional status. The two production questions deal with long-range effects of food aid on total supplies, consumption, and nutrition.

Objectives

The manifest objective of food aid to improve human nutrition presumably is derived from an underlying objective of reducing poverty, recognizing that poor health is a particularly pernicious aspect of poverty and that inadequate food is a major source of ill health.

Thus, food aid can provide a direct, immediate, and charitable means of reducing poverty. Foreign assistance took on a particularly charitable orientation following the mid-1960s as the result of impatience with the effect of earlier foreign assistance efforts to encourage growth and reduce poverty. Even the production breakthroughs of the "green revolution" tended to be discredited (Griffin). This negative attitude toward growth was reinforced by increasing concern among foreign assistance donors about its environmental effects and, more recently, the amount of energy use it required. The result was increased emphasis in the donor community on direct reduction of poverty. In agriculture, less emphasis was placed on technological change and the purchased inputs that would increase the price responsiveness of food output (Bapna). Perhaps surprisingly, more stress on direct welfare and less on elements that increase price response has not brought about increased support for food aid.

Using food aid to achieve improved nutrition need not reflect solely charitable motivations. The inability to provide adequate food to a large proportion of a country's population in the long run is reflected in an inability to accommodate those people in the political system, leading to narrowly based and unstable regimes (e.g., Mellor 1976, 1979). Thus, improving nutrition through food aid may be consistent with political objectives, but to achieve a wider political base, allocations may have to be made exceeding the narrowly defined poverty group.

Similarly, improvement in food consumption and nutrition of a broadly defined poverty group provides the basis for a stable, low wage labor force, which in turn is conducive to more labor-intensive production (Mellor 1976). In the long run, a strategy to increase employment will shift aggregate consumption toward wage goods, particularly food, to the advantage of food-exporting countries.

Dumping, direct displacement of alternative imports or domestic production, and the replacement by food aid of other forms of foreign assistance may conflict ultimately with nutrition objectives. However, these problems, which are based on different considerations, are not the subject of this paper.

In the period 1971–76, over one-third of food aid went to countries other than those designated as "needy" by the United Nations Economic and Social Council, the World Food Council, the Consultative Group on Food Production and Investment, and other international agencies. Calculations by the International Food Policy Research Institute show

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Per Pinstrup-Andersen and Shubh Kumar provided helpful suggestions.

that for the needy nations the percentage of the calorie gap (estimated by FAO) taken up by food aid ranged from 0 to 68%, with no apparent relation between the amount of food aid received and the extent of need. For a number of countries not considered needy, the amount of food aid was considerably larger than the calorie gap. It is clear that objectives other than nutrition have been major determinants of food aid allocations. There has been a tendency for critics to use this evidence of food aid allocated for political reasons to condemn it as an instrument for reducing hunger and poverty.

Market Effects on Price and Consumption

Increasing the total supply of food grains through food aid can have a major impact on nutrition by reducing market price. Use of market forces is administratively simple. Potential drawbacks, however, are distribution of substantial financial benefits to higher income people and discouragement of domestic production.

A change in food grain prices has a large effect on consumption of low income people because they allocate a high proportion of total expenditure to food grains. This is shown by Indian data. Taking into account only the income effect on the bottom two expenditure deciles, a 10% increase in food grain prices brings about a 5.5% decline in real total expenditure (Mellor 1978, p. 6). In the bottom two income deciles, food grains comprise more than half of the total consumption expenditure. Therefore, a 10% increase in food grain prices reduces their expenditure on food grains by 5.9% and their consumption by 6.6%.

A change in food grain prices also has an impact on expenditures on other commodities. Although the absolute effect is small, the percentage changes are large. For example, a 10% increase in food grain prices causes the two lowest income deciles to reduce consumption of milk and milk products by 33%. Similar percentages for other commodities suggest that changes in food grain prices have a major effect on nutrition of the poor, first, because caloric intake that is already submarginal may be significantly reduced and, second, because foods of poorer quality may be substituted for those of higher nutritional value. These substitutions may not be major; nevertheless, they have the potential to reduce the quality of the diet. Because supply can respond so little in the short run, efforts by the poor to switch to lower quality food grains will serve largely to further reduce quality differentials in price.

Using the elasticities implicit in the income effect of a price change, one can calculate the effect on income and food grain consumption of a change in supply—or for commencing or terminating a food aid program. Again, the Indian data show that a 10% decline in food grain supply would cause a 37% decline in real expenditure of the bottom two deciles (Mellor 1978, p. 11). It should be noted that in reality such a large price effect would not occur because indirect effects on employment and incomes resulting from expenditure decline by higher income classes would reduce overall food grain consumption, thereby lessening the upward pressure on prices. But the described effect on consumption is probably a reasonable depiction of the sum of price and employment effects.

Further analysis of expenditure data confirms that change in food grain supplies and prices is an efficient means of affecting consumption of food grains by low income people. Whereas a 10% increase in food grain prices reduces food grain consumption of the two lowest deciles by 5.9%, it decreases food grain consumption of the upper half of the tenth decile by only 0.2%. The absolute real expenditure on food grains is reduced ten times as much for the lowest two deciles as for the upper half of the tenth decile. In a market economy, the bulk of the adjustment to reduced supplies of food grains is made by low income consumers. Thus, food aid that adds to total supplies of food grains has a major effect on incomes, consumption, and nutritional status of low income people. An important caveat is in order, however.

To illustrate, those in the top 5% of the income distribution in India spend more than two-and-a-half times as much per capita on food grains as the lowest 20%. Thus, the upper income group experiences twice as large an effect on its overall income from a change in food grain prices as does the lower income group. Whereas food grain consumption varies little in the upper income group in response to changes in food grain prices, consumption of other goods and services varies substantially. This has two important implications.

First, these changes in consumption patterns may have important indirect employment effects on the poor. Second, there may be important inflationary or foreign exchange

effects, depending on the supply elasticities for those other commodities. The first effect is a positive one. Lower prices to higher income people are in part passed on to the poor through increased employment.

Thus, there are disadvantages in market mechanisms to allocate food aid to low income persons. Prices must be reduced substantially if there is to be a favorable effect on the poor. This has a harmful effect on production because of reduced farmer incentives, as well as on public resource allocation, and the pressure on politicians to support agricultural investment. Further, while the market efficiently allocates the food to the poor, it allocates the financial benefits substantially to the rich with consequent potential for major costs in the form of other resources. These considerations lead to interest in market interventions to shift benefits more to the poor and to depress farm prices less.

Market Interventions

Market interventions must be judged by their administrative cost, the extent to which they direct resources to the targeted group efficiently, and their political support. It is because of the need for political support that interventions often cover a group larger than the more specifically defined target group.

Two questions arise when considering targeting food aid to low income, nutritionally deficient groups. First, can an intervention be defined that narrows the recipient group? Second, does making the intervention in particular forms, specific to food, for example, increase the nutritional impact?

The question of how to operate an intervention to narrow the target group is complex. The broad food subsidy schemes of South Asia narrow the target group by using lower quality products and setting a maximum quantity (Ahmed, Gavan and Chandrasekera, George, Kumar). Further limiting of access to nonincome taxpayers is perhaps possible. Food stamps appear to be administratively and politically unwieldy for low income developing countries. Programs in India and Bangladesh are confined largely to urban areas, and these limit the target group by eliminating massive numbers of very poor rural people.

The urban bias of food subsidies is much discussed. There is strong political pressure to include the bulk of the urban population in food subsidy schemes to contain the inflationary pressures on wages of rising food prices and to abate poverty. However, the fact that food consumption of urban people is lower than that of the rural population in any given income class is important. The food subsidy program brings the urban poor up to levels of food consumption enjoyed by much lower income rural people (Ahmed). In any case, the political survival of food subsidies as well as governments seems to hinge on reaching a broad segment of the urban population.

Providing rural areas with food subsidies is a much more difficult problem. First, these areas are more difficult to reach because of poor transportation and distribution channels (Lele 1971, 1980). Second, they have a much greater total number of poor. Third, there is less political pressure to reach middle income rural people. Thus, some means of restricting entry more effectively than for the urban areas is needed and may be politically acceptable. The various types of rural employment schemes, including food-for-work, are logical approaches. The nature of the physical work will tend to restrict entry much more than does the food quality factor in urban areas, although the precise impact requires additional study. Narrow targeting, fashionable in principle, seems inefficient because of large administrative costs, considerable diversion of benefits, and failure to reach many of the poor (Desai and Gaikwad).

On the second question of improved nutrition, the research of Kumar is clear. She has calculated actual nutritional status of children by anthropometric measures and compared the effect of income from various sources on those measures. Income received in the form of subsidies on food has the largest effect on nutritional status of three income sources: food subsidies, income from own farm production, and cash income, in that order.

The effect of the source of income on consumption patterns and nutrition is derived from complex causes which probably include differences in who receives income from various sources and in consumption preferences among those recipients. Kumar's research is being pursued further to include various types of food-for-work programs and the more narrowly targeted nutrition programs. But in any case, the special efficacy of broad food subsidy programs is clear.

Despite the implementation problem, the objective of market intervention is clear. An intervention is preferred that reduces prices or

raises incomes substantially for a subset of poor people with highly elastic demand. As the policy succeeds, more food aid should reach the poor, which will reduce the inflationary pressure of food aid on other commodity prices. In addition, there will be less foreign exchange drain for other commodities, and a less depressing effect on farm producer prices.

Effects on Exporters

It is clear that like food grain producers in importing countries, food grain exporters have an interest in a set of interventions that maximizes the increase in the size of the market. In effect, the exporters also benefit from market differentiation into markets of differing elasticities and subsidization of the more elastic market. One may note that exporters have been poorly served by food aid programs of the past, which have primarily shifted imports among suppliers rather than enlarging markets (Hall; Rogers, Srivastava, Heady).

Effects on Domestic Production

The evidence clearly indicates that aggregate supply elasticities in agriculture are low—on the order of 0.1 to 0.2 (Herdt, Bapna). However, a large nutritional impact through food subsidies requires a large price decline. Thus, even with inelastic supply one must be concerned with the production effect of depressed prices. Further, the very factors that shift supply schedules may themselves be responsive to prices. Food aid may reduce the sense of urgency to increase food production in the domestic political system for recipient countries.

Thus, an important aspect of a price subsidy policy is the effect it has on the range between producer and consumer prices. A number of authors have noted that food aid provides financial resources that allow a subsidized consumer price and a considerably higher producer price (Hall; Rogers, Srivastava, Heady; George; Gavan and Chandrasekera). The result is a producer price higher than would otherwise be the case and perhaps higher than world prices, even when adjusting for exchange rate distortion. This may be the most important contribution of food aid because it allows an immediate reduction of consumer prices and hence improvement in nutrition by supplying enlarged real food supplies while it generates financial resources to support farm prices and thus contributes to th long-run solution to food and nutrition prob lems (Lele and Agrawal).

Fluctuations in Supply

If food aid is to contribute to improved nutri tional status, not only must it be reliable, but i must counter domestic supply fluctuations. I is the poor who provide the economic adjust ment to fluctuating food supplies, and yet th poor have the least physical capacity to bea such fluctuations in consumption. Also, opti mal intervention programs are politically sen sitive and cannot be easily turned on and of according to the vagaries of food aid dono objectives. Note that under great financial an international political pressure, Sri Lanka re cently cut back its food subsidies and experi enced rising death rates (Gavan and Chan drasekera). Food aid for improved nutritio must be stable; if it is not, recipient countrie should use the supply to displace more expen sive imports or to build their own stocks.

However, the food aid role can be muc more positive. Because holding stocks is ex tremely expensive, it is clear that trade is much more cost-effective means of dealin with fluctuation in production than large na tional or international stocks (Reutlinger an Bigman, McIntire). Unfortunately, the worl lacks an effective means of financing move ment of grain to meet production fluctuation in low income developing countries. Food ai could at least partially fill this gap, thereb encouraging intervention programs which fa cilitate a nutritional impact.

Conclusions

Food aid can play a substantial role in improv ing nutrition of low income people in low in come countries. It can do so because calori deficiencies are large and widespread, becaus the poor spend a high proportion of their in come on food and have high marginal propen sities to spend on food, and because tota quantities of food aid have been significan (particularly in the 1960s period of large con tributions by the United States) relative t nutritional gaps in low income countries.

Market interventions, for example, throug quality specification, modified ration schemes and employment programs, can increase th

proportion of food aid reaching the poor, thereby reducing the price-depressing effects on food producers and the price-inflating effects on nonfood commodities, as well as focus total benefits more on the poor. The minimizing of price-depressing effects, through market differentiation and the financial contribution to recipient governments of foreign food aid, allows for higher farm prices and hence greater incentive to future production than otherwise would be the case.

In practice, however, food aid has been inefficient in reaching nutrition-based objectives. First, the allocations by the United States, the dominant donor, have not been noticeably related to nutritional needs or per capita income. This is particularly true in recent years. Second, to be effective in dealing with nutritional problems, food aid must be stable or counter-cyclical to domestic production of recipient countries. That has tended not to be the case.

References

Ahmed, Raisuddin. *Foodgrain Supply, Distribution and Consumption Policies within a Dual Pricing Mechanism: A Case Study of Bangladesh.* Washington, D.C.: IFPRI Res. Rep. 8, 1979.

Bapna, S. L. "Aggregate Supply Response of Crops in a Developing Region (A Study of Ajmer District, Rajasthan, India)." Ph.D. thesis, Sardar Patel University, 1976.

Desai, G. M., and V. R. Gaikwad. *Applied Nutrition Programme, An Evaluation Study.* Ahmedabad, India: Indian Institute of Management, 1971.

Gavan, James D., and Indrani Sri Chandrasekera. *The Impact of Public Foodgrain Distribution on Food Consumption and Welfare in Sri Lanka.* Washington, D.C.: IFPRI Res. Rep. 13, 1979.

George, P. S. *Public Distribution of Foodgrains in Kerala—Income Distribution Implications and Effectiveness.* Washington, D.C.: IFPRI Res. Rep. 7, 1979.

Griffin, Keith. *Green Revolution—An Economic Analysis.* Geneva: United Nations RISD Rep. No. 72.6, 1971.

Hall, Lana L. "Evaluating the Effects of P.L. 480 Wheat Imports on Brazil's Grain Sector." *Amer. J. Agr. Econ.* 62(1980):14–28.

Herdt, Robert W. "A Disaggregate Approach to Aggregate Supply." *Amer. J. Agr. Econ.* 52(1970):518–19.

Kumar, Shubh K. *Impact of Subsidized Rice on Food Consumption and Nutrition in Kerala.* Washington, D.C.: IFPRI Res. Rep. 5, 1979.

Lele, Uma. *Foodgrain Marketing in India.* Ithaca, N.Y.: Cornell University Press, 1971.

Lele, Uma, and Mohan Agarwal. "Food Grain Imports: Whether, When and How?" *Ceres* 12(1979):20–25.

Lele, Uma, and Wilfred Candler. "Food Security: Some East African Considerations." *Food Security for Developing Countries,* ed. Alberto Valdes. Boulder, Colo.: Westview Press, forthcoming.

McIntire, John. *Food Security in the Sahel: Grain Reserves or Foreign Exchange Assistance?* Washington, D.C.: IFPRI Res. Rep., forthcoming.

Mellor, John W. *The Economics of Agricultural Development.* Ithaca, N.Y.: Cornell University Press, 1966.

———. *The New Economics of Growth.* Ithaca, N.Y.: Cornell University Press, 1976.

———. "Food Price Policy and Income Distribution in Low-Income Countries." *Econ. Develop. and Cultur. Change* 27(1978):1–26.

Mellor, John W., ed. *India: A Rising Middle Power.* Boulder, Colo.: Westview Press, 1979.

Reutlinger, Shlomo, and David Bigman. "Feasibility, Effectiveness and Costs of Food Security." *Food Security for Developing Countries,* ed. Alberto Valdes. Boulder, Colo.: Westview Press, forthcoming.

Rogers, K. D., U. K. Srivastava, and E. O. Heady. "Modified Price, Production, and Income Impacts of Food Aid under Market Differentiation Distribution." *Amer. J. Agr. Econ.* 54(1972):201–08.

The Contribution of Food Aid to Nutrition

Sylvia Lane

I interpreted the topic to mean the contribution of food aid to improved nutritional status. There is an extensive literature on this topic but the reported findings are often contradictory. I shall, therefore, attempt only to summarize some of the important highlights and viewpoints and indicate where they point to some tentative conclusions.

Food aid can contribute to improved nutritional status only if it reaches those who are undernourished or malnourished, i.e., whose nutritional status is below "satisfactory" levels however defined. The malnourished are, almost without exception, the poor whether they be the unemployed, refugees, landless, the indebted, or the women and children in low income households. Characteristically, food aid reaches the malnourished only if there are properly designed government policies. Even in the case of disaster relief, food ordinarily does not reach the hungry without government permission (Cambodia, for example).

To understand the contribution of food aid to improved nutritional status, it is necessary to understand the motivations of its suppliers, who will determine what will be available and what it will cost; the influence of the suppliers and their policies on the disposition of the food aid; the intent of international agencies promulgating nutrition programs; the motivations, nutritional policies, and programs of the demanders of food aid, i.e., the governments and government agencies of the receiving nations; and, finally, how the programs operate to improve nutritional status of those who ultimately eat the food.

Suppliers

Suppliers of food aid have, for the most part, been the countries with surpluses of agricultural products, i.e., the United States, Canada, Australia, West Germany, and others, and their motivations have been economic and political as well as humanitarian.[1] The economic motivations have been reduced in recent years as nonmarketable surpluses have in many cases decreased (particularly for grains), but they still play a part in determining the character of the commodities offered, e.g., skim milk powder from the European Economic Community (European Economic Community 1980, p. 78). Political motivations may involve strengthening the economic (and military) viability of friendly governments. Humanitarian considerations have been dominant in the case of disaster relief and relevant in many cases. Suppliers' policies and preferences have particularly influenced the type of nutritional programs adopted (the feeding of mothers and small children). These also have been influenced by such agencies as UNESCO, UNICEF, WHO, FAO, the World Bank, and international donor groups such as CARE.

It has been argued that programs aided by supplying countries and international agencies, even though they have resulted in an improvement in the nutritional status, may have acted so as to encourage dependence of recipients upon continued supplies from donor nations. This argument applies particularly to the introduction of foods unfamiliar, or less familiar, to the recipients (wheat instead of rice, reconstituted milk, corn-soymeal) and, despite the good intentions of sponsoring agencies, there may be some validity to this charge. Effects on nutritional status of food recipients may be favorable in the short run but perhaps not in the long run, unless the food aid continues indefinitely or unless being better nourished enables food recipients to increase their incomes. There have been cases where food aid commodities replaced commodities formerly bought in local markets (a free good competing with a market product)

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[1] Not that less developed countries do not help each other . . . Mexico and El Salvador helped Guatemala after their disastrous earthquake in 1976.

and local suppliers have been left without sufficient sales revenues to survive. Moreover, where specific food aid commodities have increased supply at a particular point in time in uncontrolled markets, prices have been depressed. This has caused shifting to more remunerative crops (FAO, p. 11), which may not be unfavorable to improving nutritional status in the long run.

The lower prices also may help the poor in the short run. Where markets are controlled, food and commodities can be distributed through separate channels, farm prices can be supported, and the funds from government sale of the commodities can be used to build needed agricultural sector infrastructure or to support agricultural extension services, resulting in increased agricultural income. Where the additional income accrues to poor rural households in need of food, it can contribute to improved nutritional status. Singer, the author of "The World Food Programme's Study on Food Aid Policies and Programs," contends "theoretical analysis gives no proof that food aid, *if properly handled*, has serious disincentive effects on food production in recipient countries" in the long run (FAO, p. 2).

Demanders

Demanders, in the first instance, are food-deficit countries and generally those with large low income populations that are predominantly rural (e.g., Indonesia, Central American countries, Colombia). But countries like India, Pakistan, Bangladesh, and Egypt with large urban centers also have large low-income rural populations. Where the recipients' development policies are focused on urban industrialization (Egypt), the food aid may help make "cheap" food in the cities possible. This serves to improve nutrition among low income city dwellers as opposed to low income rural residents and such food aid has been accused of having an urban bias. To quote Singer "Some critics have also pointed out that food aid usually arrives at the main port; differentiated distribution is easier to organize in the urban areas. Even projects such as the feeding of vulnerable groups are easier to set up in urban areas . . . . In addition, it may pre-empt the best storage and milling facilities" (FAO, p. 3).

Governments of recipient nations vary in their stages of development, their commitments to develop, and their attitudes toward the agricultural sector. However, there now appears to be a far greater appreciation of the role of agriculture in development (Todaro, p. 209). But this is not enough. Compulsory food sales for state purchase at below market prices, limiting or banning private sector sales, and imposed cropping patterns are still widespread and limit farmers' incomes and incentives to produce (Egypt). To quote Singer again, "The risk of disincentives does not seem to exist where the food aid is given in the form of agricultural inputs, as, for example, feed grains . . ." (FAO, p. 3).

Another problem is infrastructure (which only government will provide) and efficient market technology and institutions not being available or facilitated, resulting in farmers being paid less and consumers paying more for food with deleterious results on nutrition for low income households (Zaire; *Wall Street Journal*, p. 1). Therefore, one of the most important contributions of food aid can be making possible, through "Food for Work" projects, the infrastructure required to increase agricultural output and the movement of that output to market at lower prices. Food aid can make a long-range contribution to nutrition wherever government invests the funds from its sale in projects that improve productivity and income of low income people. If the beneficiaries are farmers, this is indeed a long-term investment.

Direct Distribution Programs

Direct distribution programs have had a measurable and positive effect on food consumption (Gavan, George). From his analysis of the effects of the program in Kerala, where food grains are distributed to low income consumers through ration shops, George concluded, "the short-term solution for areas such as Kerala is an effective public distribution system." Kumar, also studying the Kerala system, found "subsidized rice to have a positive impact on the household diet and child nutritional status greater than a cash subsidy (equivalent to the amount saved by purchasing the ration rather than open-market rice)." Kumar also found "increasing income from own-food production could result in significant improvements in child nutrition, where aggregate wages could not" and "where woman participated in the labor force,

increments in wage income (of both parents, but particularly of the mother) were associated with improved child nutritional status" (p. 41).

Thus, the evidence, although limited to specific areas, points to the effectiveness of direct distribution systems in increasing food consumption and, to some extent, nutrition. This is confirmed by the Sri Lanka study (Gavan and Chandrasekera). The use of food aid to strengthen direct distribution programs and the smallholder portion of the agricultural sector seemingly results in improvement in nutritional status (this is confirmed by Benito for Mexico) and providing work for mothers seemingly results in improvements in child nutritional status.

Supplementary Feeding Programs

Singer in his excellent summary of the literature on food aid and supplementary feeding programs (providing food directly to recipients without retail-type intermediaries) points out that in the case of expectant and nursing mothers and preschool infants, prime target groups for these programs, total coverage from all of the food aid sources put together is of the order of 5% of the potential target population (FAO, p. 44). Supplementary feeding programs "are a feasible way of raising food intake" (FAO, p. 44). But raising food intake will not, in itself, eliminate malnutrition (Scrimshaw, Taylor, Gordon). Health factors (infectious diseases, parasites), nutritional beliefs and prejudices (e.g., hot and cold foods—no hot foods for post-partem mothers), and nutritional imbalance in local diets (too many starchy staples) may lead to malnutrition. Environmental and social conditions (poor crops, inadequate incomes) and family food priorities in some cultures (lower priorities for girls and infants) also may lead to inadequate quantities of food intake and thereby to malnutrition.

Singer reviewed eleven studies dealing with effects of supplementary feeding and found eight reporting a significant short-term impact. In three, in which an attempt was made to assess the long-term effects, the results were not consistent. He concludes "the overall impact has been mixed" (FAO, p. 50). Apparently some programs, and particularly programs directed toward women and small children, have had a significant impact, and he justified the use of food aid for both supplementary feeding programs for these groups and for school age children (FAO, p. 51). Parenthetically, research (in-depth case studies) with inputs from economists and anthropologists appears to be particularly needed in this area to identify the key variables subject to control that will make these programs more effective (cost-effective) in the long run. We need household studies understanding the household as both a production and a consumption unit. If nutritional status for all household members is to improve over the long term, it may be that customs based on values and beliefs of household members will have to be changed (such as, pregnant women do not eat certain foods, men receive a more-than-proportionate or, perhaps, a required share of nutritious foods).

Johnston contends increasing employment and improving productivity, so as to increase food availability and food intake, is an effective way of improving nutritional status of older children and adults; but, he adds, there is still a need for supplementary feeding programs for women and young children. Gavan has concluded that because of the high cost of food subsidy schemes and inadequate resources of the low income countries where they are needed, "foreign assistance must meet a major part of the burden."

Conclusions

Food aid can and has been used in programs that have had a positive effect on the nutritional status of the malnourished, especially women and children, in the short run and possibly in the long run. But it can only make a long-run contribution if it is properly targeted—government policies are economically sophisticated and supportive of more rapid and improved patterns of agricultural development. The handling of the food aid must be such as to prevent or mitigate impacts on local food production and local markets. Food aid programs should be integrated with health, population, and education programs and lead to increases in real income for the malnourished poor.

References

Benito, Carlos. "Policies for Food Production and Consumption in Underdevelopment: The Case of Mexico." *J. Policy Modeling* 3(1979):383–98.

European Economic Community Commission. *The Agricultural Situation in the Community 1979 Report.* Brussels, Luxembourg, 1980.

Food and Agricultural Organization, Committee on Food Aid Policies and Programmes. *Food Aid Policies and Programmes—A Survey of Studies of Food Aid.* March 1978.

Gavan, J. D. "Commentary: Food Subsidies—Imperfect but Expedient." *International Food Policy Research Institute Report,* 1 Sep. 1979.

Gavan, James D., and Indrani Sri Chandrasekera. *The Impact of Public Foodgrain Distribution on Food Consumption and Welfare in Sri Lanka.* Washington, D.C.: International Food Policy Research Institute Res. Rep. 13, Dec. 1979.

George, P. S. *Public Distribution of Foodgrains in Kerala—Income Distribution Implications and Effectiveness.* Washington, D.C.: International Food Policy Research Institute Res. Rep. 7, Mar. 1979.

Johnston, Bruce F. "Integrated Multi-Sectoral Nutrition Interventions at the Village Level." Paper prepared for Workshop Conference on "Interface Problems between Nutrition Policy and Its Implementation," Massachusetts Institute of Technology, Cambridge, 5–8, Nov. 1979.

Kumar, Shuleh K. *Impact of Subsidized Rice on Food Consumption and Nutrition in Kerala.* Washington, D.C.: International Food Policy Research Institute Res. Rep. 5, Jan. 1979.

Scrimshaw, N. S., C. E., Taylor and J. E. Gordon. *Interactions of Nutrition and Infection.* Geneva, World Health Organization Mono. Ser. No. 57, 1968.

Todaro, Michael P. *Economic Development in the Third World.* New York: Longman Group, 1977.

Wall Street Journal, 26 June 1980, p. 1.

Public Law 480: The Critical Choices

Brady J. Deaton

P.L. 480 represents 30% of total U.S. development assistance, yet it is only a minor part of total private and public investments in recipient countries. While the U.S. share of total world food assistance declined from 94% in 1965 to 68% by 1976 (Maxwell and Singer, p. 266), P. L. 480 was still valued at roughly $1.6 billion in fiscal year 1980.[1] Moreover, P.L. 480 is viewed by both the United States and recipient nations as serving important objectives, such as meeting emergency food and nutrition needs, providing balance of payments support, and promoting economic development. Additional P.L. 480 objectives include assisting in domestic supply management, expanding markets for U.S. products, and achieving foreign policy objectives.

Among these objectives, the USDA Special Task Force on P.L. 480 gave priority to the humanitarian and developmental objectives which it felt were consistent with long-term U.S. foreign policy. In view of growing world food needs, the developmental use of food aid could be an important way of promoting employment in recipient countries and supporting their participation in world markets, particularly if the United States follows the recommendation of the Presidential Commission on World Hunger "to make the elimination of hunger the primary focus of its relationship with the developing countries." Accordingly, this paper will propose and discuss three selected conditions underlying a serious commitment to shape P.L. 480 into an effective tool for economic development. Resolution of the following three issues will require that (*a*) a politically strategic and creative international role for P. L. 480 must be firmly established and protected; (*b*) the alternative investment streams created by P. L. 480 must be identified, measured, and integrated into an investment program that fits the conditions of the recipient country; and (*c*) production disincentives in the recipient country must be minimized or avoided entirely.

A Strategic and Creative Political Role

Congress elevated the developmental role of P.L. 480 among the program's multiple goals in the 1977 amendments to P.L. 480, the so-called "New Directions" mandate. Title III was revised to encourage countries to use funds accumulated from the local sale of Title I commodities to finance mutually agreeable programs of agricultural and rural development, nutrition, health services, and population planning. To promote these developmental goals, multiyear agreements can be negotiated on the conditions and levels of future food aid shipments, and repayment obligations can be forgiven on a prorated basis as the objectives are pursued.

An effective developmental role for P.L. 480 must recognize the potential contribution of food aid: (*a*) for creating employment, particularly for the "poorest of the poor"; (*b*) for increasing domestic savings and investment; and (*c*) for enhancing more desirable spatial distributions of people and jobs. Clearly, these developmental objectives require that longer-term desirable consequences of program effects in the recipient country take priority in program planning over shorter-term political hegemony being sought by the United States. Such a commitment places P. L. 480 squarely within what Montgomery defined as a "strategic" framework for U.S. foreign policy, wherein program aims are designed to improve long-term economic and political sta-

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[1] Analysis completed for ths USDA Special Task Force on P.L. 480 (on which I served as staff coordinator) indicated that this dollar value may represent essentially no net budget outlays for the United States because P. L. 480 costs offset expenditures on domestic support programs.

bility and increase recipient countries' self-sufficiency (p. 321).

This policy stance is consistent with Liska's view of the "creative" as distinct from the "acquisitive" use of foreign aid (Liska, pp. 96–101). Creative uses are designed to achieve longer-term political and economic objectives, to recognize the evolutionary nature of political and economic change, and to shape policy consistent with long-term, sustained goals. In contrast, "acquisitive" uses of food aid would be oriented toward short-term goals and political advantages.[2]

"Acquisitive" and "creative" aid are not necessarily mutually exclusive. Acquisitive goals may have important economc consequences for creative policy, as in the case of supply stabilization and balance-of-payments support, and ultimately may lead to high priority developmental goals. In this context, acquisitive uses of food aid would receive their justification only within the purview of creative policy. This has not always been the case with the political uses of P.L. 480, as political aims have had little or no bearing on the development programs of the recipient (USDA, pp. 82–83).

A creative orientation of food aid brings economic development goals and strategic political goals into a common conceptual framework wherein their interdependence can be recognized more clearly. From the standpoint of foreign policy, a creative role places more emphasis on the second and third round consequences of policy initiatives than on short-term gains. For example, this perspective enables the market development goals of P. L. 480 to be seen more clearly as dependent on effective programs of economic development rather than on changing eating habits or inducing unnecessary economic dependency. Evidence of expanded markets for U.S. commercial exports suggests that the P.L. 480 role cannot be divorced from sustained economic progress in recipient countries.[3]

The conscious adoption of a strategic, creative aid orientation calls attention to other program modifications such as the need for a food reserve system to sustain multiyear commitments. Such a modification could help avoid the detrimental consequences, for example, of the severe food aid reductions in the early 70s.[4] The tradeoff of that period between U.S. foreign exchange benefits and the costs of losing political legitimacy in third world countries thwarted well-laid economic development programs. Schertz observed that most rich countries, including the United States, are unwilling to sacrifice foreign exchange earnings to feed the poor (p. 534). The political and economic costs of this earlier position will have to be reassessed at the highest levels of policy formation as the transition to a new international economic and agricultural order is pursued (Rothschild, p. 307).

Food Aid Investment Streams

Food aid provides a direct resource flow into the recipient country by way of concessional sales (Title I) and grants (Titles II and III). The resale of food aid in the recipient country and food-for-work provide, respectively, finances and manpower support for programs of agricultural research, extension, credit, transportation networks, and other components of rural infrastructure.

Additional resources accumulate indirectly to the recipient through wage and income effects as lower food prices result from the greater quantities of food placed on local markets and/or made available directly to consumers. Food assistance also helps minimize the threat of inflation fed by spiraling food prices, helps maintain relatively low wages, and holds the terms of trade in favor of the nonfood producing sector of the economy stimulating, in the process, profits and capital formation in the nonfood sector. Concurrently, food aid runs the risk of creating disincentives for agricultural producers unless ameliorative policy offsets the potential disincentives.

The history of most developed countries suggests that economic and particularly agricultural development occurs simultaneously with, and partly as a result of, relatively de-

[2] Strictly humanitarian and emergency uses of food aid should be placed outside this classification to avoid the irresolvable debate over U.S. motives.

[3] The most popular examples are Brazil, Taiwan, South Korea, and Spain. For further discussion of this point see USDA, *Report of the Special Task Force on P.L. 480*.

[4] Emma Rothschild pointed out that the poorest countries received in 1973 and 1974 less than one-fifth of the food aid levels received in the mid-60s, and not enough to prevent suffering from famine in Asia and Africa (p. 289). P.L. 480 wheat exports dropped from 4 million metric tons (MMT) in 1972 to 1.4 MMT in 1973 (USDA, Appendix C).

clining prices for agricultural commodities. The treadmill effect created by cost-reducing and output-expanding effects of technological change, works in favor of some farmers and against others. Even under the most labor-intensive agricultural production systems, a dynamic economy will require investments in nonfarm production to meet expanding aggregate demand and to provide employment for displaced agricultural workers. Assessing the impacts of food assistance within this dynamic framework calls attention to the alternative investment streams stimulated by injections of food aid and enables the internal rate of return to be used as one criterion in comparing the developmental consequences of each investment stream.

The initial investment stream (I_1) is generated by foreign exchange savings resulting from food aid shipments which displace other commercial imports. Even though P.L. 480 agreements require that food aid not displace commercial imports from other "friendly" nations, the Usual Marketing Requirements (UMRs), most evidence suggests that some displacement occurs.

Stevens' case studies of Tunisia, Upper Volta, Botswana, and Lesotho found that much of food aid concessional sales substituted for commercial imports, and "represented a transfer of free foreign exchange to the recipient." Hall estimated that Brazil's P. L. 480 imports displaced 89% of their tonnage in commercial imports in spite of UMR requirements. Fisher's analysis weakened the argument for UMRs by showing that the effects of "free gifts of surplus food or sales at specially [sic] low prices to underdeveloped countries are less damaging to normal export markets than simple dumping of the surpluses on the world market . . ." irrespective of the maintenance of normal food imports (p. 867). The principal justification for UMRs is to protect commercial relationships between the recipient and other "friendly" nations. Yet, Fisher's analysis demonstrates that commercial traders may benefit more from the greater total demand and stronger world prices resulting from removal of the food aid quantity from commercial markets.

The UMR can be calculated mechanically on the basis of past experience, but it may be an unreliable measure of import potential for a country experiencing rapid population growth, significant technological change in agriculture, and increases in domestic food production. Variations in these and other factors, such as the income effect of food aid, will cause the potential level of commercial imports for any given year to vary markedly from past experience.

The UMR reduces recipient country foreign exchange flexibility and, consequently, may impede economic development plans. Also, it runs the risk of biasing P. L. 480 toward more well-to-do countries which can afford the additional commercial imports. The potential balance of payments advantage of food aid is reduced in the process. Given the difficulty of enforcing UMRs and their theoretically weak justification, a reevaluation seems in order. Eliminating UMRs would turn program attention and analytical skills toward insuring an effective contribution to development of the foreign exchange freed up by food aid. Even if the UMR is strictly adhered to, the low down payment and long maturity period of Title I concessional sales enable the recipient to ration more effectively its foreign exchange, to import complementary capital goods for development purposes.

A second investment stream (I_2) created by P.L. 480 (principally public works programs and Title II) is in the form of capital produced through "food-for-work" and "self-help" programs to build roads and irrigation systems using laborers paid entirely or in part by food donations. These projects could be an important means of providing part-time, off-farm employment opportunities in rural communities.

Through innovative programming, self-help projects could be designed to promote asset ownership among low income, rural residents by creating productive capital that is owned by the laborers, or in other ways strengthening their control over income streams generated by productive assets. These steps may result in more productive uses of local savings, reduce uncertainty for peasant farmers, and stimulate entrepreneurship (Deaton). By promoting such project designs, this P.L. 480 investment stream could be an important tool for achieving optimal settlement patterns and promoting rural-urban population balance.

A third investment stream (I_3) stems from the savings generated by the income effects of relatively cheaper food and has been largely ignored in the literature. The common Engel's curve analysis provides the theoretical basis for the income effect. Isenman and Singer reviewed the intersectoral implications of the

ncome effect for inflation and induced in-
vestment, but not for the effects that may be
lerived from the investment resulting from
dditional household savings. The income ef-
ect is reallocated over the consumer budget
pased on income and price elasticities and the
narginal propensity to save (MPS). Savings
lue to the income effect are conceptually dis-
inct from savings that accrue from income
arned as wage payments under food-for-work
programs as presented in the analysis of
Srivastava et al.

The macroeconomic implications of I_3 for
lomestic savings and national investment
ould be significant. Estimates of MPS in
LDCs generally fall in the range of 10–20% for
normal income and significantly higher for
ransitory income based on consumer budget
nalysis (Hyun, Adams, Hushak; Kelley and
Williamson; Williamson). Where food aid is a
ignificant proportion of total food supply, the
potential investment effect from increased
ousehold savings should increase both the
eal quantity of savings (and investment) and
he rate of savings, assuming that the marginal
propensity to save is positively associated
with increasing income.

Schuh recently called attention to the
uman capital investment potential of food aid
which can be viewed as a fourth distinct form
I_4). This emphasis is consistent with Schultz's
Nobel lecture, which argues that improvement
n population quality is the decisive factor in
mproving the welfare of poor people (pp. 11–
4). Similar improvements may be possible
hrough institutional changes induced by food
id, such as food stamp programs (Schuh).

The Disincentive Question Revisited

The developmental role of P.L. 480 labors
nder the shadow of disincentives. The
Bellmon amendment to P.L. 480 requires that
ach country's agreement be predicated upon
he explicit determination that disincentives
or farmers in recipient countries will not re-
ult. In addition to price disincentives, policy
lisincentives may arise if recipient govern-
nents neglect their agricultural sectors be-
ause of an overdependence on U.S. food aid.

The persistence of concern about potential
price disincentives of food assistance pro-
grams attests to the power of Schultz's (1960)
eminal contribution, wherein the disincentive
ssue was raised as a theoretical possibility.
While this fear continues to haunt program administrators and has become a rallying cry for critics of the program, the bulk of evidence indicates that it is an exaggerated concern.

Two decades of research on the disincentive issue were assessed recently by Maxwell and Singer, leading them to conclude that price disincentives can probably be, and mostly have been, avoided "by an appropriate mix of policy tools" (p. 231). Only six of the twenty-one studies they reviewed reported any significant disincentives, and four of the six were based on the Indian experience. Also, Isenman and Singer criticized previous econometric work in this area for ignoring "the dynamic effects of the food aid on growth in output and employment and, hence, on demand for food grains in subsequent periods" (p. 211).

Blandford and Von Plocki respecified and evaluated earlier econometric models of food aid impacts and found that both the value and the sign of elasticity measures were sensitive to the time period studied, resulting in contrary conclusions about the price responsiveness of farmers and highly variable estimates of production declines in India. Their results call attention to the need for sensitive measurement of data for particular time periods for particlular countries and warn against generalizing beyond these particulars.

Hall's recent analysis of the effects of Title I wheat imports on Brazil's grain sector lends further support to the position that disincentives must be carefully analyzed on a country-specific basis. Hall discovered that government revenues gained by selling wheat to mills at prices above the import price were used to subsidize higher domestic price supports for producers. This effect was captured in a wheat support price equation and led to the conclusion that a sustained increase of 1,000 metric tons of P. L. 480 wheat would result in a 108% increase in Brazil's domestic grain production (p. 27).

These findings are consistent with Schuh's recent emphasis on the importance of implicit taxation schemes, common in many LDCs, to the potential incentive effect that could be created by P.L. 480. Government pricing policies generally are geared to provide low-cost food to urban populations. P.L. 480 may, in some cases, provide the leverage and resources to strengthen recipient governments' resolve to maintain sufficiently high incentive prices to rural producers.

Conclusions

Public support for a more significant developmental role for P.L. 480 is evident in recent legislative changes in the program, particularly Title III. A series of supportive and interrelated decisions of a political and economic nature will be essential if these intentions are to be realized. The purpose of this paper was to stress the interrelationships between a creative, strategic political role and a commitment to fundamental economic development programs wherein P.L. 480 serves as a productive tool for development. Although P.L. 480 is a minor proportion of total international resource flows, its developmental contribution may be significantly enhanced if the rates of return and dynamic implications of food aid investment streams are analyzed. Future research should be oriented toward meeting this objective. Simultaneously, such research should determine the complementarity between food and nonfood aid, and conditions under which incentive price structures can be created by P.L. 480. These tasks represent a formidable research and educational challenge worthy of our immediate attention, and promise high payoff for public policy.

References

Blandford, David, and Joachim A. Von Plocki. "Evaluating the Disincentive Effect of P. L. 480 Food Aid: The Indian Case Reconsidered." Dep. Agr. Econ. Cornell Int. Agr. Mimeograph 55, Cornell University, July 1977.

Deaton, Brady J. "Capital Formation in Peasant Economies." *IAAE Occastional Pap.* no. 1. (Nov. 1977), pp. 259–70.

Fisher, F. M. "A Theoretical Analysis of the Impact of Food Surplus Disposal on Agricultural Production in Recipient Countries." *J. Farm Econ.* 45(1963):863–75.

Hall, L. L. "Evaluating the Effects of P. L. 480 Whea Imports on Brazil's Grain Sector." *Amer. J. Agr Econ.* 62(1980):19–28.

Hyun, N., D. W. Adams, and L. J. Hushak. "Rura Household Savings Behavior in South Korea, 1962-76." *Amer. J. Agr. Econ.*61(1979):448–54.

Isenman, P. J., and H. Singer. "Food Aid: Disincentiv Effects and Their Policy Implications." *Econ. De velop. and Cultur. Change* 25(1977):205–37.

Kelley, A. C., and J. G. Williamson. "Household Savin Behavior in the Developing Economies: The Indone sian Case." *Econ. Develop. and Cultur. Chang* 16(1968):385–403.

Liska, George. *New Statecraft: Foreign Aid in America Foreign Policy.* Chicago: University of Chicag Press, 1960.

Maxwell, S. J., and H. W. Singer. "Food Aid to Develop ing Countries: A Survey." *World Developmen* 7(1979):225–47.

Montgomery, John D. "The Evolution of U.S. Foreig Aid." *Current History* 50(1966):321–27.

Presidential Commission on World Hunger. "Preliminar Report." Washington, D.C., Dec. 1979.

Rothschild, Emma. "Food Politics." *Foreign Affairs* Jan. 1976, pp. 285–307.

Schertz, L. P. "World Food: Prices and the Poor." *For eign Affairs,* Apr. 1974, pp. 511–37.

Schuh, G. E. "Improving the Developmental Effective ness of Food Aid." Prepared at the request of th U.S. Agency for International Development, (draft Sep. 1979.

Schultz, T. W. "Value of U.S. Farm Surpluses to Under developed Countries." *J. Farm Econ.* 42(1960) 1019–30.

———. "The Economics of Being Poor." Nobel Founda tion, Stockholm, 1979.

Srivastava, U. K., E. O. Heady, K. D. Rogers, and L. V Mayer. *Food Aid and International Economic Growth.* Ames: Iowa State University Press, 1975.

Stevens, Christopher. *Food Aid and the Developing World.* London: Overseas Development Institute 1979.

U.S. Department of Agriculture. *New Directions for U.S Food Assistance: A Report of the Special Task Forc on P.L. 480.* Office of the Secretary, Washington D.C., 1978.

Williamson, J. G. "Personal Saving in Developing Na tions: Section From Asia." *The Economic Record* pp. 194–210, June 1968.

Critical Choices in World Food Aid and Nutrition: Discussion

Benjamin Sexauer

This discussion will be broken into three segments. First, the primary objectives of food aid from the recipient and donor perspectives are enumerated for later reference. Second, a brief critique of the major points in each paper and their relationships to one another are presented. Third, a few additional thoughts on the subject, not covered by the three major papers, are provided.

Isenman and Singer provide an excellent outline of the potential benefits of food aid to a recipient country. Food assistance can (*a*) help feed the needy, either directly through subsidized distribution or indirectly by reducing food prices; (*b*) finance development projects, either directly in food-for-work projects or indirectly through generation of additional government revenues; (*c*) be used to build domestic buffer stocks to stabilize prices; (*d*) ease constraints on growth; (*e*) reduce domestic political pressures and instability. Each of these benefits can potentially affect nutrition either directly or indirectly by speeding the country's development. The motivations of donor countries may be divided into (*a*) altruism directed at either feeding hungry people or developing poorer countries, (*b*) disposal of excessive agricultural supplies, (*c*) development of future commercial demand, (*d*) support of foreign political initiatives.

The Mellor paper focuses on recipient benefit (*a*), stressing the price effect. He then progresses to the question, are there market interventions which increase the efficiency of the nutritional impact? A crucial point that Mellor makes is that market interventions must be weighed against their cost. Government administrative ability is a very scarce resource in most developing countries. Effective policy implementation may simply be beyond the capabilities of the government. Mellor points out that benefit (*e*), reducing political pressures, plays an important role in determining the structure of the intervention programs in South Asia.

The Lane paper, in contrast to the Mellor paper, focuses on direct distribution programs rather than indirect, through price reductions. She references studies which claim such programs have had a measurable positive impact on food consumption. Lane stresses the targeting of the food programs to the nutritionally most vulnerable, typically expectant and nursing mothers and pre-school children.

The Deaton paper emphasizes the potential development role of food aid, recipient benefits (*b*) and (*d*). He focuses on the use for development purposes of the revenues generated by way of concessional sales and loan forgiveness. Deaton also notes the formation of capital through food-for-work schemes. Food aid can also help lift growth constraints, particularly a foreign exchange limitation. Deaton sees hopeful signs that U.S. food aid will increasingly be used as a development tool rather than for other donor objectives.

In a crucial way the nutrition and development roles of food aid coincide since the most vital form of capital for many recipient nations is human capital formation. This perspective brings us to the recommendations of Lane for direct distribution programs to the nutritionally most vulnerable, which then brings us back to the administrative constraints noted by Mellor.

The major point to make about the possible disincentive effect of food aid is the crucial role of the recipient country's domestic policies. Mellor, Lane and Deaton, each make this point. An excellent example is the case of Brazil Deaton refers to, in which Hall found that revenues from P.L. 480 wheat were used to create incentives for domestic production. This case can be juxtaposed with Colombia, for which Dudley and Sandilands found that

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These comments are based on preliminary drafts of the papers, hence some inconsistencies may occur with the final versions. The works cited here can be found in the reference lists of the three main papers.

with P.L. 480 shipments, a substantial disincentive to domestic wheat production was allowed to arise, and production fell by 1971 to one-third of its peak levels in the 1950s. Recipient nations can not blame the donors, but only themselves, if disincentive effects occur.

On a general level, what is missing in this session is a perspective on what role can realistically be expected of food assistance. Not to sound too cynical, but such recommendations as those of the Presidential Commission on World Hunger, which advocate a major and purely altruistic role for U.S. food aid, are only rhetoric that may or may not have much bearing on reality. On the other hand, there are negative and hopeful signs in the long-run trends for U.S. food aid, the largest source of such assistance.

There has been tremendous growth in U.S. commercial agricultural exports from $3.3 billion in 1960/61 to $34.7 billion during calendar 1979. Some of the largest previous recipients of P.L. 480 aid are now among our largest commercial markets, such as Korea and Taiwan. At the peak of surplus disposal efforts in 1957, P.L. 480 shipments were equal to 68% of commercial exports. P.L. 480 now represents about 6% of commercial exports. Although the dollar magnitude of U.S. food aid has not declined, there has been a tremendous decline in the level of aid in relation to commercial agricultural trade, agricultural production levels, and the number of malnourished in the world. The era of relatively massive amounts of U.S. food assistance ended in the 1960s. Most countries, even the poorer ones, that wish to fill a gap between domestic production and consumption needs are now having to do so through commercial channels.

Additionally, the selection of recipients of U.S. bilateral food aid is still strongly influenced by objective (*d*), support of foreign policy. In 1978, Egypt and Israel received over 40% of all U.S. food exports shipped under government-financed programs.

On a more hopeful note, an increased international commitment to food assistance has developed, embodied in international agreements. Under the new Food Aid Convention of March 1980, the members of the Food Aid Committee will donate 7.6 million metric tons of cereals annually for use in developing countries. This compares with 4.2 million tons under the 1971 agreement. This new agreement is in line with trying to reach the 10 million tons of food aid annually set as a target by the World Food Conference. The United States is the largest donor, with a commitment of 4.47 million metric tons.

Even 10 million metric tons, though, amounts to less than 1% of the world production of the three major cereals, wheat, rice, and corn, based on 1978 production levels. The nutritional role food aid can be expected to play in the world is minor. The major answers to malnutrition must be found within the poor countries through expanded production, more equitable distribution, and increased employment and income. The best use to which the limited amount of international food aid available can be put is for disaster relief and in an international buffer stock role. By being available as a kind of "safety net" for countries with significant crop shortages, food aid could reduce the levels of domestic stocks required, which are expensive to maintain, and thereby have the most crucial impact on nutrition.

Estimating the Relationship between Pest Management and Energy Prices, and the Implications for Environmental Damage

ohn A. Miranowski

practicing pest management consultant re-
ntly suggested that we need to broaden our
search emphasis beyond integrated pest
anagement and consider the total crop sys-
m. Instead of our more narrow focus, a more
ppropriate area of investigation would be the
onomics of integrated crop and pest man-
gement (ICPM) systems. Components of pri-
ate crop management services may include
est, fertility, water, and soil management, as
ell as other input decisions. Yet, the key
put is improved information to assist in deci-
ion making. We need to integrate the crop
roduction and pest management decisions to
etermine the most efficient (profitable) way
produce output.

Unfortunately, a major difficulty in the eco-
omic assessment of ICPM is the lack of ap-
ropriate biological data. Many of the linkages
crop production systems are not well under-
ood or, if understood, reliable parameter es-
mates are not available. Thus, one of the
emerging issues" of the 1980s should be the
evelopment of better ICPM systems through
oth basic and applied research.

This paper considers alternative pest man-
gement systems for corn production with ris-
g energy prices. First, pest control practices
e discussed. Second, historical data are used
estimate derived demand equations for in-
cticide and herbicide treatment. Third, the
npact of rising energy prices on the future
emand and supply of pest management sys-
ms and on the implied use of insecticides is
onsidered.

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Pest Control Practices in Corn Production

To better understand the potential for adjustment to rising energy prices, knowledge of current pest control practices is necessary. The number and percentage of U.S. corn acres treated with both insecticides and herbicides have increased steadily between 1966 and 1976. Insecticide treated acres increased from 33% to 38% and herbicide treated acres from 57% to 90% (U.S. Department of Agriculture [USDA] 1968, 1974, 1978). These data are important because they indicate that pest control is a vital component of the corn production system, they serve as a crude proxy for the potential environmental hazard created, and they indicate the potential for input substitution as energy prices rise.

Although the national data provide insights into current pest control practices, they provide little information on the potential for ICPM systems. Data for 1977 Iowa corn production, presented in table 1, are helpful in assessing the potential for improved management systems for corn insect control. Soil insecticides were used on 58% of all corn acres and on 91% of continuous corn acres. Although chemicals were the predominant control technique, cultural practices (crop rotations) were used widely.

The insecticide treatments in table 1 were primarily for corn rootworm (CRW) control. Of the 50%–51% of the Iowa corn acres treated in 1978 and 1979, 44%–45% were reportedly treated with a CRW insecticide (Becker and Stockdale). Entomological recommendations suggest that chemical CRW treatments are usually required only for corn following corn rotations. Yet, 25% of the corn following soybeans and 43% of the corn following other crops received insecticides in

Table 1. Acres of Crop Treated with Soil Insecticides in Iowa, 1977

	Corn Following Corn	Corn Following Soybeans	Corn Following Other Crops	Total Acre Treated
Total planted ('000 acres)	6,261	5,886	1,354	13,500
Total treated ('000 acres)	5,696	1,492	579	7,766
Percent treated	91	25	43	58

Source: Jennings and Stockdale.

1977. Additionally, Taylor cites studies that indicate that CRW insecticide use on continuous corn could be reduced over 50% with little or no loss of yield. The possible overuse of insecticides may be accounted for by lack of information to interpret indicators of potential damage and the desire to reduce variability of yield losses.

Relationship between Pest Control and Energy Prices

As relative energy prices rise, what adjustments will occur in pesticide use? Historical data are available to estimate separate derived demand equations for insecticide and herbicide treatment in corn production. Cross-sectional data for the ten USDA agricultural regions are pooled for 1966, 1971, and 1976. The empirical specification of the derived demand models for insecticide and herbicide treatment of corn acres is[1]

(1)

$$\ln ST_i = a_0 + a_1 \ln P_i + a_2 \ln P_F + a_3 \ln y + a_4 \ln SCA + a_5 \ln RE + \ln P_L + e_i,$$

where ST_i is the share of corn acres treated with insecticides or herbicides; P_i, the price of insecticides or herbicides; P_F, the price of fuel; y, the value of corn output per acre; SCA, the share of corn acres in cropland acres; RE, the lagged production-oriented research and extension expenditures; P_L, the farm wage rate; e_i, the error term; and ln denotes the natural logarithm.

The dependent variable is specified as the share of acres treated with insecticides or herbicides. The insecticide and herbicide treatment data, as well as data on share of corn acres in cropland acres, are from the USD. pesticide surveys (USDA 1968, 1974, 1978 The input price indices, P_i and P_F, are region; averages derived from data in *Agricultur Prices—Annual Summary* and P_L is fro *Farm Labor*. The values of corn output pe acre are based upon prices from *Agricultur Prices—Annual Summary* and yields from *Ag ricultural Statistics*. Prices are deflated b the index of all farm production input price from *Agricultural Statistics*. The productior oriented research and extension expenditure are the aggregate value lagged five years fro Cline. These expenditures are deflated by a index of average salaries of college and un versity teachers. Unfortunately, these est mates are not available for corn alone, so th aggregate expenditures are used.

The following relationships are hypothe sized for the insecticide and herbicide deman models. First, increasing the price of insec ticides or herbicides should reduce the shar of acres treated. Second, a positive relatior ship between fuel prices and herbicide trea ments is expected. As energy prices rise, re duced tillage systems become more profitabl relative to conventional tillage systems, whic use more mechanical (fuel) and less chemic (herbicide) weed control. Even though the ne energy saving from reducing tillage and sul stituting herbicides is not large, it is usuall significant. The relationship between fu prices and insecticide treatment is less certai but hypothesized to be positive. If herbicide and insecticides are treated as joint inputs int reduced tillage, fuel price increases that lea to tillage reductions may increase the deman for insecticide treatment. Also, as energ costs and thus total production costs rise farmers may apply more insecticides to pro tect their production cost investment, com parable to a "wealth effect." Third, increasin the value of the crop per acre should increas the demand for treatment. Fourth, ln SCA re flects the intensity of the monocultural env

[1] As Katherine Reichelderfer suggests in her comments, the levels of pest infestation should be included as independent variables in the production function and in the derived demand equations. Generally, historical data on pest infestation in corn production are unavailable.

ronment. A greater share of corn acres in a region will result in more serious insect, especially *CRW*, and weed problems and thus a greater demand for pest control. Fifth, research and extension expenditures serve as a proxy for the availability of improved information and the efforts to develop alternative pest control techniques. In the case of insecticides, a negative relationship between insecticide treatment and ln *RE* is hypothesized, given the possible overuse of chemical control and the potential of alternative insect management strategies. The relationship to herbicide treatment is uncertain. Finally, a positive relationship between herbicide treatment and the wage rate is expected. As the price of labor increases, herbicides are substituted for labor in the production process.

Separate, weighted, least squares regression models for insecticide and herbicide treatment are reported in table 2. The regressions are weighted by corn acres in the region. Two herbicide demand models are reported, one with and one without the price of labor. The results are generally consistent with the hypothesized relationships and contain interesting implications about the magnitude of pest control response to rising energy prices. Given the log specification of the models, the estimated coefficients are also elasticities.

Table 2. Estimates of the Demand Equations for Insecticide and Herbicide Treatment of Corn Acres

	Insecticide Treatment	Herbicide Treatment	
Exogenous Variables	(1) ln ST_I	(2) ln ST_H	(3) ln ST_H
Constant	−47.50	−9.14	−7.69
	(−2.87)	(−1.66)	(−1.64)
ln P_I	−.78	−.75	.03
	(−.53)	(−4.03)	(.10)
ln P_F	15.17	4.42	3.99
	(2.96)	(2.63)	(2.79)
ln P_L			1.89
			(3.22)
ln y	2.97	.69	.27
	(3.27)	(2.36)	(.97)
ln *SCA*	.19	.22	.22
	(.73)	(2.57)	(3.06)
ln *RE*	−1.43	−.44	−.34
	(−1.66)	(−1.58)	(−1.39)
R^2	.36	.67	.77
Observations	30	30	30

[a] *t*-statistics in parentheses.

The empirical results contain the following price effects. First, rising fuel prices increase the demand for both corn insect and weed control treatments. As fuel prices rise, farmers substitute the relatively cheaper chemical cultivation for fuel and mechanical cultivation. Possibly because of the joint nature of pesticide inputs or to a "wealth effect," a similar relationship occurs in insect control. Second, when the wage rate is not held constant, increasing insecticide and herbicide prices decrease the demand for insecticide and herbicide treatment, respectively. However, the coefficient on insecticide price is not significantly different from zero. Likewise, the herbicide price coefficient is not statistically different from zero if the wage rate is held constant. Third, when the wage rate is included in the herbicide model, it has a positive impact on the demand for chemical weed control, implying a labor-herbicide substitution.

Increasing the value of the crop per acre increases the demand for both insecticide and herbicide treatment. The elasticity is greater for insecticides and reflects, not unexpectedly, the increased demand for crop protection as crop value increases. Increasing the concentration of corn production in a region has a positive and significant impact on weed control problems. Although the coefficient on the share of corn acres has a positive sign in the insecticide demand model, surprisingly, it is not statistically significant.

Finally, lagged research and extension expenditures have a negative impact on the demand for insecticide and herbicide use. This variable reflects the impacts of both improved alternatives for pest control and improved knowledge of pest control needs. Although it does not allow us to determine the substitution possibilities between information and energy in corn production systems, it does indicate that information and alternative pest control strategies are potentially substitutable for chemical control in corn production. This result is more significant in corn insect control, where evidence of potential overuse exists.

The results in table 2 may be a better indicator of what has happened than of what is going to happen as improved ICPM systems evolve for corn production. Such management systems likely will substitute information for chemicals, especially in insect control. To illustrate future corn pest management choices as energy prices rise, the tradeoffs between alternative systems for corn rootworm control

will be evaluated, including the impact of rising fuel prices on the cost of supplying pest-monitoring services, and on the demand for alternative pest control techniques.

Impact of Energy Prices on Pest-Monitoring Costs

Although many pest information services initially are funded by public or private grants, eventually the services must switch to a more permanent funding source (e.g., Extension Service) or become a self-sustaining private enterprise. Given the limited pest-monitoring activities currently occurring in corn production, actual monitoring cost data are not available. Also, few studies of the cost of producing pest management information in other crops are available (Grube and Carlson; Hall, Willey, and Norgaard).

To assess the cost of supplying pest-monitoring services and to estimate the impact of rising fuel prices, the following pest-monitoring cost model is employed:

$$(2)\quad M = \{[ng + (n + 1)(1 - g)][m(v + f + .05\,w) + wt] + OC\}/a,$$

where M is pest-monitoring costs per acre; n, trips to fields that exceed the threshold infestation level; g, probability of a field exceeding the threshold level; v, vehicle cost per mile; f, fuel cost per mile; m, average distance to participating fields (miles); w, wage rate paid to scouts; t, $1.6 + .0067\,(a - 40)$ = sampling time per field of 40 acres or more (Steffe, 1979); OC, overhead cost of monitoring service per field; and a, acres per field. In constructing this model, it is assumed that the probability of fields exceeding the threshold infestation can be determined and that nonthreshold fields require an additional sampling.

To derive estimates of the impacts of rising fuel prices on the per acre cost of supplying pest monitoring services, the following parameter values are specified: $n = 3$, $g = .5$, $v = \$.21$, $w = \$5.00$, $OC = \$15$, $m = 15$, and $a = 40$. At fuel costs of \$1.00, \$2.00, and \$3.00 per gallon, the costs of supplying monitoring services equal \$1.81, \$1.94, and \$2.07 per acre, respectively.

Fuel costs do not significantly affect the costs of supplying monitoring services to corn producers. More profound cost impacts will result from comparable relative changes in other cost components including program participation (i.e., reducing average distance to fields), wage rates paid to scouts, and trips to fields. Likewise, the rise in monitoring costs due to energy price rises will be overshadowed by the increase in insecticide costs due to rising energy costs. A doubling of fuel costs will increase scouting costs approximately 5%–10%, but the expected rise in insecticide prices would be more significant (Pidgeon).

Pest Management Choices with Rising Energy Prices

To evaluate the impact of fuel costs on the choice of CRW management in corn production, the cost of supplying monitoring services, M, is included in the profit function specification,

$$(3)\quad y_j = \frac{\sum_{i=1}^{n} [p_i(1 - s_j)\,Y_i - C_i - M_{ij} - I_{ij} - F_i - N_i]}{n},$$

where y_j is profit per acre for ICPM strategy j; p_i, price per unit for crop i; s_j, expected corn yield loss due to CRW damage for ICPM strategy j; Y_i, expected yield per acre for crop i assuming no CRW damage; C_i, costs of production per acre for crop i excluding fuel, fertilizer, pest control, and land charge; M_{ij}, pest monitoring costs per acre for crop i with ICPM strategy j; I_{ij}, insecticide costs per acre for crop i with ICPM strategy j; F_i, fuel costs per acre for crop i; N_i, fertilizer costs per acre for crop i; and n, number of crops in rotation. This specification of the profit (net returns) function is used to simulate the impact of changing fuel prices on the ICPM choice at the farm level. The model is designed to incorporate the impact of rising fuel prices on insecticide, fertilizer, and pest monitoring costs as well. For simplicity, we consider only a limited range of pest control alternatives—soil insecticide, crop rotation, and monitoring with treatment-as-needed. Although other biological, cultural, and adult control techniques are possible alternatives, the cases considered provide an informative illustration of the impacts of rising energy prices on ICPM choices.

The empirical data used in the model are from unpublished sources. The enterprise budget data are from Extension Service circulars of Iowa State University and from U.S.

Department of Agriculture (1976). Additionally, the following assumptions are utilized: (*a*) corn price—$2.50 per bushel; (*b*) soybean price—$6.25/bu.; (*c*) corn yield—120 bu./acre; (*d*) soybean yield—36 bu./acre. The yield loss assumptions are based upon insecticide field evaluation studies from the Corn Belt states. The impact of energy price rises on fertilizer and pesticide prices are based on Pidgeon.

Seven crop and pest management systems are considered in the analysis. Table 3 lists the strategies and reports the results of the model runs for 1.0, 1.5, 2.0, and 2.5 times current energy prices. Under current fuel prices, CC-M is the most profitable crop and pest management alternative, but only slightly more profitable than the CC-I (prophylactic control) alternative. But as energy prices rise, some interesting adjustments occur in the profitability of control alternatives. First, monitoring becomes more profitable relative to prophylactic soil insecticide treatment on the CC and CCS rotations. Second, the cultural control systems (CS) become more profitable than CC-I and CC-M as energy prices continue to rise.

Two caveats are in order. First, we have assumed constant relative prices for corn and soybeans. If the relative price of corn increases with rising energy costs, the CC rotation may remain more profitable. Yet this will encourage the substitution of pest monitoring and chemicals-as-needed for cultural practices. Even though the environmental implications of CC-M may not be as positive as the crop rotation alternatives, it will encourage a substitution away from prophylactic soil insecticide treatments and reduce chemical use. Second, the model is based upon a number of assumptions concerning monitoring costs, yields, yield losses, input costs, and output prices. If these assumptions are inaccurate for particular situations, or if certain coefficients change over time, shifts in the profitability of alternative ICPM systems may result. Third, we have ignored the impact of a farmer's risk preference on the choice of pest control technology. If a producer exhibits risk-averse behavior, the prophylactic soil insecticide treatment may be preferred even if profits are lower (Miranowski; Miranowski, Ernst, Cummings).

Conclusions

Based upon this analysis, it is reasonable to conclude that as energy prices rise: (*a*) weed and insect control will be substituted for fuel inputs in corn production; (*b*) information (monitoring) services will be substituted for insecticide inputs in corn production; (*c*) systems analysis provides a useful framework for assessing the impacts of rising fuel costs on the choice of management strategies for CRW control; and (*d*) environmental quality impacts are ambiguous because we cannot ascertain if the pesticide for energy substitution will be offset by the information for pesticide sub-

Table 3. Net Returns under Alternative Crop and Pest Management Strategies for Corn with Rising Energy Costs

Pest Control Strategy	Net Returns[a] ($/acre) 1.0x Fuel costs	1.5x Fuel Costs	2.0x Fuel Costs	2.5x Fuel Costs
CC[b] — N[c]	112	99	86	72
CC — I[d]	121	107	93	79
CC — M[e]	122	109	95	81
CS — N	117	106	96	86
CCS — N	112	100	88	77
CCS — I	115	103	91	80
CCS — M	115	103	92	81

[a] Including returns to the land input.
[b] CC is continuous corn; CS is corn-soybean rotation; CCS is corn-corn-soybean rotation.
[c] N is no CRW control regardless of need.
[d] I is CRW soil insecticide applied regardless of need.
[e] M is pest monitoring program with insecticide only as needed.

stitution in the pest control production function.

References

Becker, Roger, and Harold Stockdale. "Pesticides Used in Iowa Crop Production in 1978 and 1979." Iowa State University Coop. Extens. Serv. Bull. Pm-964, July 1980

Cline, Philip. "Sources of Productivity Change in United States Agriculture." Ph.D. thesis, Oklahoma State University, 1975.

Grube, A., and G. Carlson. "Analysis of Field Scouting and Insecticide Use." Mimeographed. North Carolina State University. 1978.

Hall, D., W. Willey, and R. Norgaard. "Productivity and Profit of Pest Control Technology in California Citrus." Mimeographed. University of California-Berkeley, 1975.

Jennings, Vivan, and Harold Stockdale. "Herbicides and Soil Insecticides Used in Iowa Corn and Soybean Production, 1977." Iowa State University, Coop. Extens. Serv. Bull. Pm-845, Sep. 1978.

Miranowski, John A. "Integrated Pest Management in Corn Rootworm Control: A Preliminary Economic Assessment." Paper presented at the AAEA annual meeting, Washington State University, July 1979.

Miranowski, John A., Ulrich W. Ernst, and Francis H. Cummings. "Crop Insurance and Information Services to Control Use of Pesticides." EPA 600/5-74-018, Sep. 1974.

Pidgeon, Edward R. "Energy Conservation Possibilities in Corn Production on a Central Iowa Farm." M.S. thesis, Department of Economics, Iowa State University, 1977.

Steffe, Kevin L. "Spatial Dispersion and Population Estimation of Northern and Western Corn Rootworm Adults in Iowa Cornfields." Ph.D. thesis, Department of Entomology, Iowa State University, 1979.

Taylor, C. Robert. "Alternative Pest Management Strategies for Food Production in the Corn Belt." Mimeographed. Working paper prepared for the Office of Technology Assessment, U.S. Congress. June 1978.

U.S. Department of Agriculture. *Agricultural Prices—Annual Summary*. SRS, Washington, D.C., 1967, 1972, 1977.

———. *Agricultural Statistics*. Washington, D.C., 1977.

———. *Costs of Producing Food Grains, Feed Grains, Oilseeds, and Cotton, 1974–76*. ERS Agr. Econ. Rep. No. 338, Washington, D.C., June 1976.

———. *Extent of Farm Pesticide Use on Crops in 1966*. ERS Agr. Econ. Rep. No. 147, Washington, D.C., Oct. 1968.

———. *Farm Labor*. SRS. Washington, D.C., Jan. 1968, Jan. 1972, Feb. 1977.

———. *Farmers' Use of Pesticides in 1971 . . . Quantities*. ERS Agr. Econ. Rep. No. 252, Washington, D.C., July 1974.

———. *Farmers' Use of Pesticides in 1971 . . . Extent of Crop Use*. ERS Agr. Econ. Rep. No. 268, Washington, D.C., Sep. 1975.

———. *Farmers' Use of Pesticides in 1976*. ESCS Agr. Econ. Rep. No. 418, Washington, D.C., Dec. 1978.

———. *Quantities of Pesticides Used by Farmers in 1966*. ERS Agr. Econ. Rep. No. 179, Washington, D.C., Apr. 1970.

Economic and Biological Variables Affecting Demand for Publicly and Privately Provided Pest Information

Gerald A. Carlson

Several recent national reports have directed attention to policy changes in pest information programs. An Office of Technology Assessment report gives as a major conclusion, that there is a lack of an adequate delivery system which impedes the dissemination of data necessary to support effective pest management decisions. A lack of practical, demonstrated interdisciplinary programs has resulted in grower skepticism and uncertainty regarding the economic benefits of integrated pest management (IPM). To remove the obstacles to IPM, the OTA report gives congressional options that include among others:

(*a*) federal support for IPM training including establishing regional pest management study centers;

(*b*) creation of a federally coordinated pest and weather monitoring program, support of public information delivery systems, incentives for the formation of private information delivery systems, and increased support for state plant health clinics;

(*c*) and an attempt to overcome grower conservatism of IPM through grower education, direct grower incentives, or regulation of growers.

The Council of Environmental Quality also has a report with many of the same findings and recommendations as the OTA report. In addition it calls for a feasibility study of an "early warning system" to identify problems in controlling significant pests with chemical pesticides. It recommends development of model certification requirements for independent IPM consultants and investigation of insurance schemes for farmers participating in IPM programs.

These policy recommendations require evaluation before adoption. There are serious questions about how the extension service should assist growers and consultants. In what form, if any, do private consulting firms need assistance? Licensing, liability and crop insurance, specializied training, and loan subsidies have been proposed. In addition, the role of more conventional grower training and crop decision making may be changing.

This paper will survey past attempts of economists and biologists to model pest control "delivery systems." I will assume that delivery of pest control information includes the functions of (*a*) private consultants, laboratories, and scouts; (*b*) individual growers and grower organizations; (*c*) chemical industry salesmen and fieldmen; and (*d*) various public organizations. To simplify, let me ignore IPM research and the role of fieldmen and concentrate on the interaction between public and private sector IPM information.

Previous IPM Consulting–Scouting Studies

There has been steady progress in the use of rigorous techniques and instruments for monitoring pests. Light traps have been used for at least eighty years for sampling agricultural pests (Sterling). Classical and sequential sampling techniques have given precision to estimates of pest populations and crop damage (Sterling). Bayesian decision procedures have allowed current observations to be combined with subjective probabilities of pest infestation for improved pest control decisions for risk-averse farmers. In recent years discoveries of pest phermones and assay methods have

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helped lower the cost of monitoring and identifying many pest species. Computers, satellites, and other communication instruments probably will further the possibilities for monitoring in pest management (Rabb and Kennedy).

Economic analysis of professional scouts is not a new topic. Paid specialists in insect scouting were operating in Arkansas as early as the 1930s, but they did not rapidly expand in number until the 1950s (Lincoln, Boyer, Miner). Willey provided the first analysis of California consultants. He found that farmers who were more risk-averse and had more contact with extension were more likely to hire consultants. The farmer's confidence in the quality of the information of the consultants as measured by their length of time in business was found to be another important feature in the adoption of consultant services. Hall continued the evaluation of California consultants over a longer period. His major focus was on showing that consultant-using farmers expended less for pesticides per acre. Grube found evidence of both complementary and substitute relationships between scouting and pesticide use. His production function showed a statistically significant yield increase from more insect scouting per season.

Other economic studies have directed attention to the interaction between farmer and hired pest monitoring. Pridgen analyzed cotton insect monitoring across the cotton belt. She found that farm size, extension subsidies and farmers' off-farm opportunity costs increased the probability of farmers hiring IPM services. She also found that higher consultant fees and farmer education decreased the use of these services. Grube showed that there were more total (hired and self) field inspections per season when expected pest damage and farmer managerial ability were higher.

None of the above studies have investigated the spatial aspects of IPM services. The question of the effect of extension activities on the profitability of similar private IPM practices has not received adequate analysis. Also, there seems to be a need for a model which can evaluate future changes in state licensing of consultants and the regional training center proposal.

Delivered IPM Advice

To facilitate the discussion, let us divide the production and dissemination of IPM advice into three components: transportation-communication, monitoring activities, and diagnosis and recommendations. The components have primarily the same focus regardless of whether the main labor source is farmers, scouts, consultants, or extension (public information). Consider momentarily this to be a model of supply of private consulting service.

The transportation-communication function is more important for pest management inputs than other agricultural inputs because of the frequent need for timely service, specific to a particular field. Production of the transportation-communication component (t) is dependent upon capital (cars, two-way radios, telephone, computers) (K), professional consultant time used in travel (T), lay labor travel time (L), farmer travel time (F) and the particular configuration of roads and crop density in the area (d):

$$t = t(K,T,L,F,d). \tag{1}$$

The field-monitoring function has had considerable long-run input from research on sampling under various crop, environmental, and pest conditions. At the operational stage it usually involves monitoring crop growth status and beneficial insects, as well as pest status at the field level. Regional public pest monitoring, weather conditions, and crop status changes can serve as indicators for sequential sampling schemes. Also, machines and traps do not have the human monitoring bias of erroring on the high pest count side to prevent unexpected large crop losses. The production of monitoring (m) can be written as

$$(m) = m(K,T,L,F,I,f), \tag{2}$$

where the first four monitoring inputs (K,T,L,F) have the same identification as in equation (1), I is public monitoring information (extension news letters, radio reports, or weather bulletins), and f refers to the particular field sizes that are in a region.

The final component of delivered IPM advice is that of diagnosis and recommendations. In some cases this component can also include IPM decision making such as when a farmer asks his consultant to contract for pesticide applications, or other actions. Alternatively, it can be entirely a grower function when he receives only monitoring reports and not recommendations from scouts. This function depends much more on stocks of knowledge on the part of growers, consultants and extension

specialists. The recommendation (r) function is

$$(3) \qquad r = r(T,F,I,N,s),$$

where T is professional consultant time in giving recommendations, F is farmer time in consultation, I is extension input in providing specific actions given specific pest conditions, N is the stock of knowledge of the consultants and the farmers, and s is farm size. Farm size is important since uniform recommendations for all acreage of a given crop on a farm can be given in a single farmer-consultant session. Each session may have considerable set-up costs.

Total production of IPM advice includes each of the three components. If one omits capital and lay labor, since they are fairly constant across all regions, then the final IPM advice (A) production function is

$$(4) \qquad A = A(T,F,N,I,d,s,f).$$

By assuming that IPM consulting firms are profit-maximizing firms whose services are divisible and excludable between customers, then one can derive a supply curve for professional consultant advice (A^s):

$$(5) \qquad A^s = A^s(F,N,I,T,d,s,f,A_p).$$

A_p is the contract price per acre-year for the consultant firm advice, and A^s is advisory services measured in acres. Advice supply is not easily observed, but numbers of consultants is. Professional consultant time is an input in IPM advisory service. Given that there is some constant labor-leisure choice by consultants, then the demand for consultants has the same arguments as equation (5) plus consultant wages (T_p):

$$(6) \qquad T^D = T^D(F,N,I,d,s,f,T_p).$$

The stock of knowledge (N), public information (I), and farmer time (F) are considered to be substitutes for consultant time in (6). More consultants will be demanded where regional crop density (d), large field (f), and farm size (s) favor lower cost provision of services per acre.

Grower Demand for IPM Advice

Grube and Hall have shown that scouting and consultant advice can enter the agricultural production function. Consider a simple single-crop production function:

$$(7) \qquad V = V(P,A',O),$$

where V is yield of crop output, P is expected pest density, A' is the level of all types of advice on pest management, and O represents all other imputs. The derived demand for the advice input is

$$(8) \qquad A'^D = A'^D(P,A'_p,O_p,V_p),$$

where the p subscript denotes the purchase price for the advice and other inputs, and V_p denotes crop value. However, this is not the demand for consultant advice, since A' is composed of advice from extensionists, the farmer himself, and consultants. Including the selection between type of advice leads to

$$(9) \qquad A^D = A^D(I_p,F_p,V_p,A_p,O_p,P).$$

In this demand for a farm input equation, the cost of using extension information (I_p) and farmer advice price (opportunity cost of farmer time) (F_p) are expected to increase the demand for consultants.

With no barriers to entry into consulting, then market-clearing prices for advice should determine the equilibrium number of consultants. If there was state certification of consultants, then consultant wages need not be equal across location. The reduced form of equations (6) and (9) can be written as

$$(10) \quad T = T(P,I,V_p,N,s,F,f,d,A_p,F_p,I_p,O_p).$$

This model could be used to evaluate each of the major sources of IPM advice. A model similar to this one has been used by Taylor to estimate the regional distribution of veterinarians. He found that having a school of veterinarian medicine in a state does not increase veterinarian density. This model should enable one to evaluate the geographical effects of the proposed IPM training centers and the regional specificity of other IPM training.

For a test of this model for private consultants, consider a simplification of equation (10) in which crop density, consultant fees, farmer opportunity cost and time, extension information cost, and all other input prices are assumed constant across regions. Field and farm size (s) will be measured by acres per farm, expected pest level (P) will be measured by pesticide expenditures per crop acre in an earlier period (Blake and Andrilenas), and public information (I) is measured by the number of extension and state IPM specialists. The stock of knowledge of farmers and consultants in a region (N) is measured by regional

cotton production. Cotton has a long history of IPM consultation, and IPM experience has been accumulated by consultants and farmers in those regions growing cotton. Crop value is crop value per acre of crop produced. The final model to be estimated is

$$(11) \qquad T = (P, I, V_p, N, s).$$

One of the most difficult problems is finding a good measure of private IPM consultants. There are many crop consultants who are not IPM specialists. Also there is no association to which all IPM specialists belong. The Intersociety Consortium for Plant Protection (ICPP) performed a survey of land-grant university department heads in 1978 (ICPP). They obtained estimates of numbers of IPM consultants (M.S. and Ph.D.), scouts (B.S.), IPM extension specialists, and departments of agriculture IPM specialists by states. Table 1 shows a regional tabulation of their results. The scout category undoubtedly includes individuals who only work at IPM about three to four months per year. The number of independent consultants shows a high degree of variability by region.

Analysis of Regional IPM Consulting

The effect of extension and other public IPM specialists is not unambiguous in the above IPM advice model. More extension effort in monitoring and recommendations will lower the supply price of consultant time and increase the supply of consultants in a region for a given consultant advice demand. On the other hand, lowering the price of extension specialist information (I_p) can lead to its substitution and reduced consultant demand. For example, it would be difficult to sell nematode assays if extension provides the same information at a lower cost.

A final estimation problem is present in the model of equation (11). The crop value (V_p), the level of pesticide expenditures (P), and public employees (I) may not be exogenously determined. However, on a regional basis, expected crop value may not be determined by numbers of consultants even though it may be at the farm level. Using the lagged, regional, pesticide expenditure level to indicate expected pest level should also help with the simultaneity problem. Only pesticide data other than herbicides was used because of the lack of variability in herbicide practices, and the general absence of IPM consultants for weed problems. For the public employee variable one may be able to argue that the public employees preceded the private ones in time.

The regional estimate of the reduced form equation for consultants was estimated by least-squares using the data of table 1. The estimated regional model of consultants per million crop acres with t-values in parentheses is

$$\begin{aligned}(12) \quad T = -.53 &+ \underset{(2.00)}{.47P} + \underset{(2.26)}{.07V_p} + \underset{(.93)}{1.49s} \\ &+ \underset{(11.46)}{.03N} - \underset{(-1.92)}{.37I} \quad R^2 = .98.\end{aligned}$$

Each of the variables has the expected effect. The demand side substitution effect of the public IPM service (I) outweighs the supply effect to give a negative influence on number of consultants.

Table 1. Number of Public and Private IPM Specialists, 1978

Region[a]	Scouts (B.S.)	Independent Consultants (M.S., Ph.D)	IPM Extension Specialists	State Department of Agriculture
Northeast	40	9	24	17
Lake States	117	15	16	14
Corn Belt	126	31	33	20
Northern Plains	94	41	20	10
Appalachia	142	5	43	9
Southeast	150	33	35	15
Delta States	115	85	18	29
Southern Plains	137	118	48	7
Mountain	112	30	29	35
Pacific	317	113	20	29
U.S. Total	1,350	486	286	185

Note: Estimates were made by department heads in crop protection disciplines at land-grant universities (Intersociety Consortium for Plant Protection).
[a] See USDA pesticide use surveys (Blake and Andrilenas) for regional delineations.

The elasticities computed directly from equation (12) are .34, .52, .11, .7 and −.4 for expected pests, crop value, farm size, knowledge stocks, and public employees, respectively. The relatively large impact of cotton production probably measures season length and pest complexity, as well as accumulated experience. A data set which had direct measures of experience could separate these effects. The highly significant effect of cotton production on consulting needs further analysis. These preliminary results suggest that further analysis should be undertaken.

There is no analysis of the substitution possibilities between consulting and pesticide use n the model above. To see what type of information is being collected on concurrent use of pesticides, nonpesticide controls and consulting, let us turn to recent USDA pesticide use surveys.

USDA Pesticide Use Surveys

The nonpesticide information gathered in the latest USDA pesticide-use surveys is extensive. In recent years, there is a distinct trend toward asking farmers more about their nonpesticide pest control practices at the same time that pesticide use is measured. There are fourteen separate surveys completed or in process. Beginning with the 1977 cotton survey, questions on target pests, scouting, and farmer management practices were first collected. Target pest tabulations give which common pest species farmers believe they are controlling with particular pesticide applications (in eight surveys). Infestation levels referring to farmer estimates of the relative level of pest attack are given in six surveys. The physiological stage of the crop when pesticides were applied was compiled for six surveys.[1]

The scouting data collection is limited in scope, but three surveys have collected fees charged, and seven will have some tabulation of type of scout employed or source of scouting information. Some questionnaires merely ask "sources of information." There does not seem to be a consistent way of tabulating farmer scouting in the survey, and often it is omitted. The studies by Willey and Grube point to the need for complete information on amount and quality of self- and hired scouting.

[1] The author can provide a table summarizing major items in each survey and the sample size for each survey.

For the USDA pesticide use surveys to be most effective for evaluation of IPM information services, there need to be some modifications. First, minimal farmer demographic data is necessary to estimate farmers' opportunity costs of time. Consultant and farmer IPM experience also should be tabulated. Average field and crop acreage sizes per farm will also be helpful in evaluating transportation. Use of traps, IPM computer links, and other capital items also could be easily tabulated.

This study separates the IPM advice process into three components and provides a supply and demand model which can be estimated. With a limited, regional set of data encouraging results were obtained. More complete data from USDA pesticide use surveys may permit better specification of such models. Policy questions on IPM information certainly require more attention by economists and biologists.

References

Blake, H. T., and P. A. Andrilenas. *Farmers' Use of Pesticides in 1971 . . . Expenditures*. Washington, D.C.: U.S. Department of Agriculture Agr. Econ. Rep. No. 296, Nov. 1975.

Council of Environmental Quality. *Integrated Pest Management*. Washington, D.C., 1979.

Grube, A. H. "Economic Analysis of Field Scouting and Insecticide Use in Cotton Production." Ph.D. thesis, North Carolina State University, 1979.

Hall, D. C. "An Economic and Institutional Evaluation of Integrated Pest Management with an Empirical Investigation of Two California Crops." Washington, D.C.: Environmental Protection Agency, 1977.

Intersociety Consortium for Plant Protection. *Integrated Pest Management*, A Study for the Experiment Station Committee on Organization and Policy. Agr. Res. Serv., North Carolina State University, Sep. 1979.

Lincoln, C., W. P. Boyer, and F. D. Miner. "The Evolution of Insect Pest Management in Cotton and Soybeans: Past Experience, Present Status, and Future Outlook in Arkansas. *Environ. Entomology* 4(1975):1–7.

Office of Technology Assessment. *Pest Management Strategies*, vol. 1, 2. Washington, D.C., 1979.

Pridgen, S. G. "Farmer Selection of Cotton Insect Management Services: Collective Control and Scouts." Ph.D. thesis, North Carolina State University, 1980.

Rabb, R. L., and G. G. Kennedy, eds. *Movement of Highly Mobile Insects: Concepts and Methodology in*

The Nature of Benefits and Costs of Use of Pest Control Methods

C. Robert Taylor

Integrated pest management (IPM) strategies are often strongly advocated as a means of increasing farm income while at the same time decreasing pesticide use and thus the external costs associated with pesticides. These impacts, though they may be true for some individual producers, are not necessarily the final outcome of widespread adoption of IPM. Emphasis of this paper is on the nature of such paradoxes and the conditions under which they can occur. Although the focus of the paper is on effects that are manifested in the marketplace, other effects such as external costs of pesticides and nonproducer costs for developing and/or implementing IPM are included for completeness.

A mathematical treatment of the paradoxes is given to add concreteness to the paper. But before proceeding with a mathematical treatment, it may be useful to take a superficial, graphical look at the paradox that while individual producers may gain from adopting IPM, income to producers as a group will not necessarily increase with widespread adoption. The classical explanation of this paradox is that with inelastic demand, total revenue, and thus profit, would decrease with an increase in production attributed to adoption of IPM. Of course, early adopters would reap windfall gains, but as more and more producers adopt IPM, aggregate income would decline. Although this classical argument is valid for a perfectly inelastic supply curve, it is not usually appropriate to the analysis of IPM because it does not account for impacts on production cost. That is, to measure farm income effects, one must take an a priori view of the supply curve rather than viewing supply a posteriori. When this view is taken, it can be seen that inelastic demand is not necessarily a condition for aggregate farm income to decrease with widespread adoption of IPM. Figures 1 and 2 illustrate these points. In figure 1, it can be seen that a shift in supply resulting from adoption of IPM will increase producers' surplus which, for purposes of this paper, is equated with farm income including the rent to fixed factors of production. Note, however, that figure 2 illustrates a case where aggregate income will decrease, even with elastic demand. In this case, supply shifts more at high prices than at low prices, which is typically the case with pest control methods since low cost producers tend to be those without serious pest problems.

Social Welfare Impacts

Complete mathematical treatment of benefits and costs that are manifested in markets, and the distribution of these values, requires specification of a Walrasian system of multiple horizontally and vertically related markets. However, for expository convenience, consider only two horizontal market levels, specifically the markets for raw agricultural products and the markets for inputs to agricultural production. Also for expository convenience, only five groups of economic actors are considered: (*a*) producers of agricultural products, (*b*) consumers of raw agricultural products, (*c*) input suppliers, (*d*) people who bear external costs or derive external benefits from production and/or input usage, and (*e*) those who pay the social overhead costs of IPM. While these groups are usually not mutually exclusive, the surplus doctrine in conjunction with the compensation criterion implies that social welfare can be measured by

$$(1) \quad W = \Pi_Q + CS_Q + PS_x + E - G,$$

where W is net social benefits; Π_Q is the profit or rent accruing to producers; CS_Q is consumers surplus measured in general equilibrium in the raw agricultural product markets, which is surplus for final consumers plus all forward

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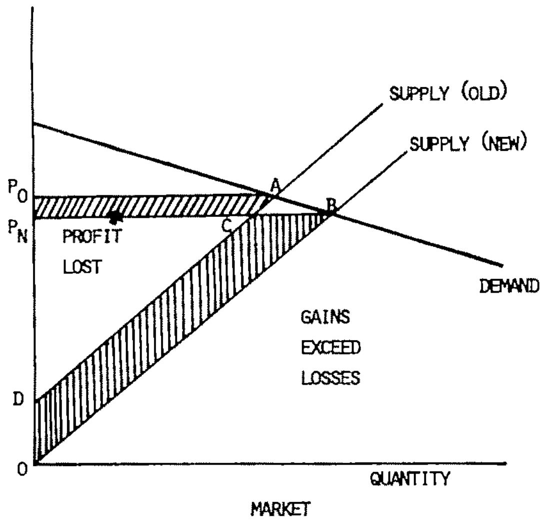

Figure 1. Situation where aggregate profits increase

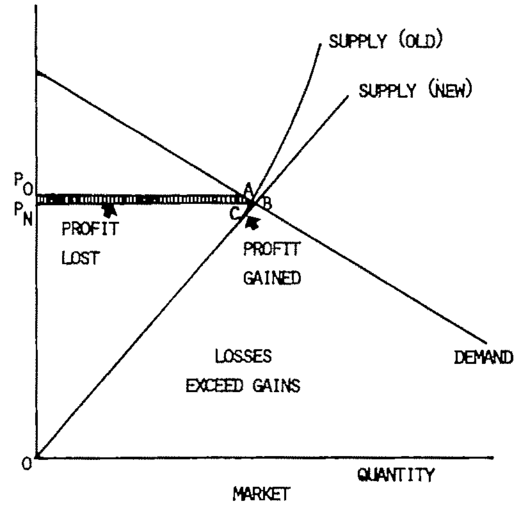

Figure 2. Situation where aggregate profits decrease

rents; PS_x is producers surplus in the input markets, which is rent in input markets plus all backward rents plus surplus for raw material suppliers (Collins; Chavas and Collins; Just and Hueth); E is external benefits (costs); and G is the social overhead cost for IPM programs.[1]

Most IPM strategies represent a distinct and discrete change from conventional pest control. However, before turning to discrete changes, it is perhaps instructive to consider an infinitesimally small change in the mix of pest control technologies and information systems. Letting M be a proxy variable denoting the technology-information mix, the change in net social benefits for an infinitesimally small change in M will be

$$(2)\quad \frac{\partial W}{\partial M} = \frac{\partial \Pi_Q}{\partial M} + \frac{\partial CS_Q}{\partial M} + \frac{\partial PS_x}{\partial M} + \frac{\partial E}{\partial M} - \frac{\partial G}{\partial M}.$$

Let us now examine each of the terms on the right-hand side of equation (2) for a multiproduct, multi-input case. Mathematical treatment of profit effects of changes in a factor such as M commonly begins with an assumption about optimizing behavior on the part of producers. Here, however, it is not essential to make any restrictive assumptions about optimizing behavior; rather, the analysis can be based on an assumed behavioral relationship. Then the analysis can focus on the profit incentive to adopt and the aggregate impacts of adoption. Consequently, consider a behavioral relationship for a multiproduct producer, postulating that acreage of the jth crop depends on per acre net returns of that crop and competing crops:[2]

$$(3)\quad A_{ij} = \bar{A}_{ij}\,(R_{i1}, \ldots, R_{iJ}),$$

where A_{ij} is acreage of the jth crop for the ith producer; and R_{ij} is per acre net returns, defined to be

$$(4)\quad R_{ij} = P_j\, Y_{ij} - \Sigma_k\, r_k\, X_{ijk},$$

where P is the per unit price of the jth product; Y_{ij} is per acre yield; r_k is price of the kth input; and X_{ijk} is per acre input usage. The set of X's can be defined to include application rates for each pesticide used or which can be used, different methods of scouting for insects, and all nonpest control inputs. An implicit production function relates Y_{ij} to X_{ijk}. Production of the jth crop by the ith producer will be $Q_{ij} = A_{ij}\, Y_{ij}$, and total production of the jth crop will be $Q_{\cdot j} = \Sigma_i\, A_{ij}\, Y_{ij}$.

Profit Impacts

Profit to the ith producer can be represented by the profit function,

[1] The result that PS_x measures backward rents and CS_Q measures forward rents is, however, derived from profit maximization assumptions in other markets.

[2] Equation (3) can be derived from profit maximization for some production relationships and constraints. A more general case would have $\bar{A}(P, Y, r, X)$. Results based on this more general case are similar to results based on (3), but (3) is used for notational convenience.

(5) $\Pi_i = \Sigma_j A_{ij} R_{ij} = \Sigma_j \tilde{A}_{ij} R_{ij}$,

which can also be expressed as

(6) $\tilde{\Pi}_i = \Sigma_j (P_j Y_{ij} - \Sigma_k r_k X_{ijk}) \tilde{A}_{ij}$.

Since individuals view product demand and factor supply as perfectly elastic, the incentive for an individual to adjust the IPM technology-information mix, M_i is[3]

$$(7)\quad \frac{\partial \tilde{\Pi}_i}{\partial M_i} = \Sigma_j (P_j Y_{ij} - \Sigma_k r_k X_{ijk}) \frac{\partial \tilde{A}_{ij}}{\partial M_i} + \Sigma_j \left(P_j \frac{\partial Y_{ij}}{\partial M_i} - \Sigma_k r_k \frac{\partial X_{ijk}}{\partial M_i} \right) \tilde{A}_{ij}.$$

Equation (7) will be positive, zero, or negative, depending on whether the producer is underutilizing M_i, using the profit-maximizing M_i, or overutilizing M_i. The remaining analysis in this paper will focus on the case where (7) is positive, since this is the case commonly encountered in pest control.

Consider now the impacts of increased adoption of IPM, or increased use of M_i, on industry profits. Summing over producers, industry profits can be represented by

$$(8)\quad \tilde{\Pi}_Q = \Sigma_i \tilde{\Pi}_i = \Sigma_i \Sigma_j (P_j Y_{ij} - \Sigma_k r_k X_{ijk}) \tilde{A}_{ij}.$$

Because it is usually not appropriate to assume perfectly elastic product demand and factor supply at the industry level, the change in industry profits will be:[4]

$$(9)\quad \frac{\partial \tilde{\Pi}_Q}{\partial M} = \Sigma_i \frac{\partial \tilde{\Pi}_i}{\partial M_i} = \Sigma_i \Sigma_j (P_j Y_{ij} - \Sigma_k r_k X_{ijk}) \frac{\partial \tilde{A}_{ij}}{\partial M_i} + \Sigma_i \Sigma_j \left(P_j \frac{\partial Y_{ij}}{\partial M_i} + Y_{ij} \frac{\partial P_j}{\partial M_i} - \Sigma_k r_k \frac{\partial X_{ijk}}{\partial M_i} - \Sigma_k X_{ijk} \frac{\partial r_k}{\partial M_i} \right) \tilde{A}_{ij}.$$

Rearranging terms, equation (9) can be expressed as

$$(10)\quad \frac{\partial \tilde{\Pi}_Q}{\partial M} = \Sigma_i \left[\Sigma_j (P_j Y_{ij} - \Sigma_k r_k X_{ijk}) \frac{\partial \tilde{A}_{ij}}{M_i} + \Sigma_j \left(P_j \frac{\partial Y_{ij}}{\partial M_i} - \Sigma_k r_k \frac{\partial X_{ijk}}{\partial M_i} \right) \tilde{A}_{ij} \right] + \Sigma_i \Sigma_j \left(\tilde{A}_{ij} Y_{ij} \frac{\partial P_j}{\partial M_i} \right) - \Sigma_i \Sigma_j \Sigma_k \left(X_{ijk} \frac{\partial r_k}{\partial M_i} \right).$$

The first term in brackets on the right-hand side of (10) can be related to equation (7) which shows the individual incentive to adopt M. As noted previously, we are interested in the case where individuals are underutilizing M_i; hence, the first term in brackets in (10) will be positive. Note, however, that the last two terms in (10) can have any sign, depending on industry adjustments as translated into price changes. The direction of impact is easier to see in the case of a single product. If adoption of IPM results in an acreage and output increase and thus a product price decrease, the second term on the right-hand side of (10) will be negative. The final term can be either positive or negative, depending on whether the weighted value impact on input usage increases or decreases. Hence, equation (10) can be either positive or negative, depending on changes in production, input usage, and the slopes of general equilibrium product demand and factor supply curves.

Effects on Input Use

Industry use of the kth input will be

$$(11)\quad X_{\cdot\cdot k} = \Sigma_i \Sigma_j X_{ijk} \tilde{A}_{ij}.$$

The change in total use of the kth inputs used in agricultural production, resulting from adoption of IPM, will be

$$(12)\quad \frac{\partial X_{\cdot\cdot k}}{\partial M} = \Sigma_i \Sigma_j X_{ijk} \frac{\partial \tilde{A}_{ij}}{\partial M_i} + \Sigma_i \Sigma_j \tilde{A}_{ij} \frac{\partial X_{ijk}}{\partial M_i}.$$

An interesting paradox relating to total pesticide use can be examined with equation (12). If an increase in M involves reduced per acre use of pesticides, the last term in (12) for a pesticide input will be negative. However, the first term on the right-hand side of (12) will be positive if acreage expands as a result of adoption of M. Thus, total pesticide use can increase, even though the intensity of pesticide use decreases.

Impacts on Surpluses and Net Social Welfare

Consider now the impacts on net social welfare, equation (2), of a change in M. Close inspection of equation (10), which shows the

[3] A product subscript, j, was not included for M because pest control on different crops may be interrelated. The variables X_{ijk} and Y_{ij} are implicit functions of M_i; thus R_{ij} and $\tilde{A}_{ij}$ are also implicit functions of M_i.

[4] Due to the connection between individual firms' decisions and market price, the price P_j is an implicit function of M_i, for all i. Similarly, r_k is an implicit function of M_i, for all i.

impacts on industry profits, will reveal that the next to last term is the negative of the change in consumer surplus:

$$(13)\quad \frac{\partial CS_Q}{\partial M} = -\Sigma_i\Sigma_j\left(\tilde{A}_{ij}\, Y_{ij}\frac{\partial P_j}{\partial M_i}\right)$$

$$= -\Sigma_i\Sigma_j\, Q_{ij}\frac{\partial P_j}{\partial M_i}.$$

Similarly, the last term in (10) is the negative of the change in surplus for producers of X:

$$(14)\quad \frac{\partial PS_X}{\partial M} = \Sigma_i\Sigma_j\Sigma_k\left(X_{ijk}\frac{\partial r_k}{\partial M_i}\right).$$

Substitution of (10), (13), and (14) into (2) gives:

$$(15)\quad \frac{\partial W}{\partial M} = \Sigma_i\Big[\Sigma_j(P_j Y_{ij} - \Sigma_k r_k X_{ijk})\frac{\partial \tilde{A}_{ij}}{\partial M_i} + \Sigma_j\Big(P_j\frac{\partial Y_{ij}}{\partial M_i} - \Sigma_k r_k\frac{\partial X_{ijk}}{\partial M_i}\Big)\tilde{A}_{ij}\Big] + \frac{\partial E}{\partial M} - \frac{\partial G}{\partial M}.$$

In the absence of externalities, E, and social overhead costs, G, equation (15) will be nonnegative for any adjustment in the set M_i, which moves individual producers closer to the individual profit-maximizing level of M_i. Thus, we have the familiar result that if one or more producers are not using the profit-maximizing level of M, social welfare can be increased by an adjustment in the set M_i that moves it to, or closer to, the privately optimal level. However, whether these benefits accrue to producers, consumers, or both depends on the specific case considered.

With externalities and social overhead costs, equation (15) can be of either sign. In one case, the social overhead cost changes, $\frac{\partial G}{\partial M}$, could outweigh any benefits manifested in the marketplace. In another case, the change in external costs could be negative because total pesticide use would increase with adoption of IPM, as was illustrated with equation (12).

Lumpy Changes in IPM

For lumpy changes in M, impacts on industry profits can be obtained by integrating (10) from the initial M to the final M. Similarly, impacts on total use of pesticides, consumer surplus, surplus for input suppliers, and net social welfare can be obtained by integratior of (12), (13), (14), and (15), respectively. Although space does not allow for mathematica specification of these integrals, it is very important for empirical work to note that integration must be from one general equilibriun point to a new general equilibrium point. Fo example, in estimating impacts on consume surplus, which is the integral of (13), integration must be along a set of general equilibriun demand functions where all other prices in th economy are allowed to adjust. Thus, for em pirical work it is imperative to have a mode that either explicitly or implicitly accounts fo general equilibrium adjustments. Worded an other way, empirical estimates based on par tial equilibrium curves, which are typically es timated in econometric models and are im plicit in many other aggregate models, wi give biased results, with the magnitude of bia depending on how strong markets are interre lated.

Another word of empirical caution is that t compute the effects of IPM on aggregat profit, we are usually better off using a direc profit function rather than the area above product supply curve and below price. Th only case where the two measures are equiva lent is if the supply curve is also a margina cost curve. In practice, we seldom kno whether supply is marginal cost, so use of th area above supply and below price may i clude factors such as risk premium and expec tations that are never realized.[5]

Mathematical derivations given above we for the adoption of an IPM technolog information mix, under the assumption that M $= M_i$ for all i. The derivations also hold f other changes, such as a technology chan (Chavas and Collins) or a pesticide ban. C course, for a lumpy change, one must use th appropriate integration points, which will di fer from the case discussed above.

Concluding Remarks

This paper has attempted to provide a co crete explanation of some of the paradox

[5] If the supply curves shown in figures 1 and 2 are gene equilibrium marginal cost curves and the demand curves are ge eral equilibrium relationships, it can be shown that integration (15), excluding E and G, for a lumpy change in M will give t measure of welfare change that is shown in these figures. Ho ever, if the supply curve does not reflect marginal cost, then o must use a profit function to measure the impacts of widespre adoption of IPM on industry profits.

The case of unrealized expectations can be seen by setting

associated with widespread adoption of integrated pest management. IPM is often "sold" on the basis that it increases farm income and decreases pesticide use. Neither of these claims can be taken as a foregone conclusion. Generally, consumers will benefit from IPM through relatively lower food prices, and the component of social welfare that is manifested in the marketplace also will increase. But whether aggregate farm income will increase or decrease and whether net social benefits will increase is a moot point that can only be answered by empirical studies.

Empirical analysis of the aggregate economic impacts of widespread adoption of IPM is challenging indeed. Even more challenging is educating lay people on the paradoxes associated with widespread adoption of IPM, or for that matter any technology.

a profit maximization model, but assuming that the producer consistently over- or under-estimates the marginal physical productivity of pesticides. Then the area above the derived supply curve and below price will measure expected profit, which will never be realized. This seems to be a plausible case in regard to pesticides.

References

Chavas, Jean-Paul, and G. S. Collins. "Multimarket Welfare Implications of a Non-Price Distortion." Mimeographed. Texas A&M University, 1980.

Collins, G. S. "A Generalization of Some Welfare Measures in a Multi-Market Framework." M.S. thesis, Oklahoma State University, 1980.

Just, R. E., and D. Hueth. "Welfare Measures in a Multiproduct Framework." *Amer. Econ. Rev.* 69(1979): 947–54.

Economics of Integrated Pest Management: Discussion

Katherine H. Reichelderfer

Pest managment offers numerous opportunities for challenging economics research. Investigation of the economic aspects of agricultural pest control is in high demand. This area of research, however, is fraught with potential problems. I will use the three papers presented in this session to illustrate some common problem areas.

Good interdisciplinary communication is essential to the success of empirical investigations of pest management and other agricultural issues. Economists and plant protection scientists are dependent upon one another for data, methodology, and research results. As Swanson has aptly pointed out, economists must take care to be sure that they understand the biological system with which they are working and also must transmit a good understanding of economic systems to the biological science community. Taylor's paper is an attempt to avoid some of the problems that can arise from a lack of such mutual understanding. His careful explanation of the range of possible outcomes of a change in pest control technology is a vital exercise in transdisciplinary communication.

Data problems abound in pest management economics and are evident in Carlson's and Miranowski's papers, and in almost every other empirical work in this area. There are a variety of ways of coping with these problems, but often "solutions" create new problems. For example, Carlson follows a questionable practice in using pesticide expenditures as a proxy for expected pest level. This implicitly assumes that farmers have good knowledge of pest level expectations (in which case they need no advice) and base pesticide purchase and use decisions on that knowledge. The proxy also distorts any effects of the differences in pesticide materials and prices among regions. The use of proxies, or omission of variables necessitated by lack of data, may be unavoidable. But following such practices requires strong qualification of research results.

Economists typically express production as a function only of variable and fixed inputs, as Miranowski has done in his paper. The use of input quantities rather than a measure of pest infestation level to represent the impact of pest control on yield is a common practice but not a preferred approach. Pest control affects pests. It is the pests, rather than direct productive inputs, that affect yield. The productivity of a unit of pest control is completely dependent upon target pest numbers. There exists, in essence, a family of production functions for a given pest control input, each showing the effect of varying rates of control on a single pest level and the subsequent effect of reduced pest numbers on yield. Production functions for pest control are unrealistic if they do not express yield as a function of pest levels. This problem should be kept in mind by anyone estimating pest control productivity or substitutability with other inputs.

Another common, but often necessary, assumption that may create problems in empirical studies of pest control options is that of the profit incentive. Previous studies (Farnsworth; Miranowski, Ernst and Cummings) indicate that risk perception or risk aversion are more compelling bases for pest control decisions than is profit maximization. Evidence also is available to suggest that the real value of many pest management practices is reflected in a change in yield or income variability rather than a change in average expected yield or profit (Hall). Conclusions such as Taylor's that are based on studies that assume the profit incentive should be carefully interpreted.

Much of the popular demand for a change in pest control technology is related to social costs of pesticide use. However, little empirical work on the net social welfare aspects of agricultural pest control has been conducted.

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This probably is related to the difficulty in estimating the external effects of pest control actions (see LeBaron). Taylor uses an "*E*" to represent a variable that, for lack of data and/or appropriate valuation techniques, is often ignored or discounted.

Generalization and oversimplification are enticing, but dangerous courses to follow in examining the complex issues of pest management economics. Taylor has been careful, in one sense, to warn us of this problem. However, he, like others, makes some assumptions that may have created an error similar to the one he sincerely warns against. His assumption that "supply shifts more at high prices . . ., which is typically the case . . . since low cost producers tend to be those without serious pest problems" may be true for cotton production, but is it valid across the board? Our familiarity with one cropping system, region, or pest problem must not be allowed to affect our overall perspective or approach to empirical work on integrated pest management (IPM).

A last potential problem is one not relevant to the papers presented in this session, but that deserves attention nonetheless. The intertemporal aspects of pest-control decision making and productivity are sometimes disregarded in empirical works that otherwise would benefit by their inclusion. Changes in input productivity depend upon the stage of crop development, rate and age structure of the pest population, and a range of other dynamic variables. The economic implications of such variables can be significant and should, when they are relevant, be considered.

Some of the problems discussed above are avoidable and should be addressed whenever possible. Others, like lack of data, may be relatively unavoidable in the short term. It is, in part, the need to address these problems and derive approaches for their resolution that makes the economic study of IPM so challenging.

References

Farnsworth, Richard L. "A Decision Theroretic Analysis of Alternative Pest Control Strategies: A Case Study of Cotton Growers in California." Ph.D. thesis, University of California, Berkeley, 1980.

Hall, Darwin C. "The Profitability of Integrated Pest Management: Case Studies for Cotton and Citrus in the San Joaquin Valley." *Bull. Entomolog. Soc. Amer.* 23(1977):267–74.

LeBaron, Allen. "Economics as a Basis for Policy Decisions." *Utah Science* 32(1971):63–72.

Miranowski, John A., Ulrich W. Ernst, and Francis H. Cummings. "Crop Insurance and Information Services to Control Use of Pesticides." Washington, D.C.: Environmental Protection Agency, EPA 600/5-74-018, Sep. 1974.

Swanson, Earl R. "Working with Other Disciplines." *Amer. J. Agr. Econ.* 61(1979):849–59.

Economics of Integrated Pest Management: Discussion—An Entomologist's View of IPM Research Needs

William G. Ruesink

Ten years ago it would have been difficult to find four economists with working experience in integrated pest management (IPM). Today we have four on the program and they probably represent only 5% to 10% of the world's investment into the economics of IPM. Thus, while the number is still small, it is growing rapidly. As an entomologist, I am delighted to see this increase and to hear the presentations today. I must say I find little to criticize and much to be optimistic about. In view of this and because an entomologist rarely has the opportunity to address an audience of so many economists, I will use my time to present one entomologist's views on the needs for future research in IPM. In doing so, I will indicate which of those needs I see as best fulfilled by economists and biologists working together and which can best be fulfilled by each of the two groups working separately.

First, consider the research which should be a joint effort. Foremost on this list is to join with systems scientists to develop a holistic overview of pest management. Such an overview would include defining the goals of IPM, identifying the component parts of an IPM system and the boundaries of that system, discovering the inputs and outputs of the system, and so on. This probably should be done for several specific crop production systems, for example, the corn-soybean cash-crop system of this part of the country. As part of this effort, we should develop several lists of criteria for "good" pest management. I say several lists because I propose we need one for the growers' point of view, another for the local community, a third for the region, a fourth for the entire country, and perhaps one for the world. These lists can serve as points of reference whenever we evaluate a particular IPM program.

Another joint effort is the development of proposals for alternative IPM programs. The biologists possess technical information about agronomic and environmental relationships, while the economists work with the social and economic aspects. Ideas leading to these proposals will be generated in part by the first joint effort and in part by the several separate efforts which follow.

There are three efforts which should be largely the responsibility of the biologists. One is to develop an understanding of the relationship between crop yield and pest population level. At its simplest, this relationship is expressed as a univariate equation with population level measured at a single point in the life cycle of the pest. More generally the relationship includes temporal dynamics to account for the variation in crop yield that results from variation in pest population over time. Another task for the biologists is to quantify the impact of PM actions on pest populations. For example, what does crop rotation do to next year's corn rootworm population? A third task is to develop models for change in pest populations. Given a set of environmental and management conditions, and an initial pest population, a method is required that forecasts changes in population level over time. And of course, the biologists must design experiments and sample surveys to obtain the data needed for these three tasks.

There are also three tasks which are largely the responsibility of economists. One is to develop farm level budgets for each alternative PM program. These probably must be disaggregated enough so differential effects can be detected by region and by grower classification. Another task is to evaluate each alternative against the several lists of criteria, that is for the grower, the community, the nation

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etc. The third task is more of a request: Please tell the biologists what you need and how important each need is. Do you need the models I have assigned to the biologists? Are deterministic models adequate or should we invest a significant part of our resources into quantifying risk? Or, does the biologist even know what an economist means by risk? Finally, just as the biologist must gather data, so also must the economist. Do not complain to me that you cannot find data on how much corn is grown under rotation versus under continuous culture. You must design and execute sample surveys or use whatever other means you have available to acquire the information needed to accomplish the above tasks.

In closing, I appeal to biologists, economists, and everyone interested in IPM to remember the word "pest" has no biological or ecological significance. Pest management is only important when it benefits mankind. Our job is to develop IPM programs that are, over the long term, socially and economically best for the largest possible number of people.

The Political Economy of Rural Development
(Sidney Evans, North Carolina A&T State University, Presiding)

A New Approach to Nonmetropolitan Development: National Sectoral Policies

Pat Choate

The stimulation of economic development in nonmetropolitan areas lies as much in efforts to strengthen the overall economy and the vitality of specific industries and groups of linked industries, called "sectors," as in traditional area development policies.

Revitalizing the overall economy, its parts, and that of specific places—metropolitan and nonmetropolitan—will involve three interdependent courses of action: (*a*) improving capital formation and productive investment, (*b*) accelerating the development and application of new technologies, and (*c*) improving labor quality. Although these principal elements of a national economic revitalization effort are relatively clear and the potential benefits to nonmetropolitan areas relatively obvious, there is less clarity both on how to proceed and on the capacities of nonmetropolitan areas to participate fully in such an effort.

The purpose of this paper is threefold: (*a*) explore present economic and institutional circumstances that are key to national economic and economic revitalization, (*b*) describe how national sectoral policies can be used to guide national economic revitalization, and (*c*) assess the development capacities of nonmetropolitan areas to participate in a process of national economic revitalization.

A Changing Economy

During the past two decades, there has been a major shift of investment and employment from metropolitan to nonmetropolitan areas. This shift has made these nonmetropolitan areas sensitive to those international and domestic economic changes that affect specific firms, industries, or groups of linked industries—sectors. For example, as the fortunes of the domestic automobile assembly firms have declined, dozens of linked supply firms, such as tires, batteries, plastics, and steel, also have been adversely affected. Because many of these assembly and supply firms are located in nonmetropolitan areas, the effects of change have rippled through specific places and affected specific employment groups.

The creation of targeted national, state, and local economic strategies in the future will require increased reliance on microapproaches, approaches targeted to specific industries and sectors. The creation of such approaches requires a critical evaluation of national economic weaknesses and strengths that eventually must be addressed. Specifically, a number of indicators are cause for concern, including:

The United States' rate of productivity growth has fallen for almost a decade and a half. In 1979 and in the first quarter of 1980, actual productivity levels fell. This key economic indicator suggests that the United States is losing its competitive edge with international competitors whose productivity has declined but at not nearly the rate experienced in the United States.

Structural unemployment and high inflation have become a seemingly permanent feature of the U.S. economy. The present administration in its *1980 Economic Report of the President* predicted that unemployment would not reach 4% levels until 1985, and inflation would not be reduced to 3% levels until 1988.

Firms of other nations are capturing an increasing share of both domestic and international markets formerly serviced by U.S. companies. The difficulties in steel, automobiles, textiles, apparel, and shoes are merely the most obvious. Even seemingly thriving industries such as semi-conductors and computers are now potentially at risk.

Although these signs of economic decline are cause for alarm and action, economic and

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political panic must be avoided. The U.S. economy is strong and has all the key elements necessary for a restored economic vitality and growth. For example:

Although other nations have closed overall productivity levels, the United States remains the most productive among major industrial powers.

The size of the domestic economy is a major asset. Specifically, the $2.4 trillion-U.S. economy remains the largest single market in the world. The combined value of the gross national product (GNP) of the nineteen members of the European Organization for Economic Cooperation (OECD) is only slightly larger than that of the United States.

During the decade of the 1970s, the U.S. economy was able to absorb over 20 million additional workers, an increase roughly equal to the entire work force of either Italy or France.

Although other nations are increasing their competitive position in technology, the overall U.S. technological base is still the most advanced in the world.

The Changing Role of Government

A contemporary economic and political reality is that virtually all decisions by business and entrepreneurs are now shared with government. This expanded role of government in the economy is a consequence of the growth of public interventions through a diverse and interdependent array of fiscal, monetary, trade, area development, and regulatory activities.

The multiple economic interventions of the public sector are distinguished by their size, scope, directive influence, and their policy and administrative disarray. The disorder in public economic interventions is producing a number of unwanted, even unanticipated, side effects that in aggregate seem to retard overall productivity. In large measure, this disorder reflects the use of antiquated techniques of public administration, such as large-scale patronage, even though disguised under civil service labels. This disarray also reflects the absence of either macro- or micro-national development objectives.

At present, national development policy essentially consists of a number of discrete individual programs and regulatory activities. The responsibility and authorities for the policies and administration of these multiple interventions is fragmented among and between the many agencies of the federal government, the fifty state governments, and the more than 79,000 units of local government.

The inefficiencies and adverse consequences contained in public economic interventions have not gone unnoticed. For at least three decades, a diverse number of efforts have been initiated to bring rationality to these economic interventions. The principle of these efforts have been reorganization efforts, creation of a variety of intergovernmental planning requisites, coordination approaches, and the use of numerous "advanced" management techniques such as planning, programming and budget control, and zero-based budgeting. These approaches have produced some results, but on the whole they have failed. For example, since 1948, there have been twenty-eight major attempts to reorganize the economic policy machinery of the federal government now located in thirty-three separate departments and agencies outside the Executive Office of the President. Yet, the policy disarray continues as does the structural fragmentation.

Pluralism, both structural and issue, is a strong force in the U.S. political and economic system, which must be recognized if improved public administration of the nation's economic interventions is to be achieved.

A New Approach to Nonmetropolitan Development

The most promising and efficient approach for bringing coherence to government's many economic interventions and to public, nonmetropolitan development policies/programs is the creation of economic strategies targeted to specific industries and groups of linked industries (sectors).

Industrial and sectoral policies essentially would be a process by which government, business, and labor would openly and cooperatively devise a set of common economic objectives (long- and short-term) and identify the respective roles and responsibilities each party would have. This common framework would provide a needed source of logic and discipline for government's many economic interventions and at the same time increase needed conditions of certainty for business and labor.

National sectoral policies would have a

number of basic characteristics, including: they would be more inclusive than the current, limited concepts of reindustrialization. Rather, sectoral policies would recognize the role and interdependence between manufacturing, agriculture, finance, services, resources, and other parts of a total economy. Such policies would be formulated in the context of general economic goals (macro-objectives) of reducing inflation and unemployment and of increasing per capita GNP. Such policies would harmonize the objectives of balanced growth between regions and between metropolitan and nonmetropolitan areas. And, they would assist in bringing better balance between the nation's efficiency, equity, and quality-of-life objectives.

In creating national sectoral policies, the initial focus would be on three categories of economic activities: (*a*) those having high growth potential; (*b*) those basic, mature, but essential economic activities such as steel production; and (*c*) those distressed economic activities such as apparel which eventually will drift to a lower level of production and employment because of strong international competition. Strategies for each of these three categories of economic activities would vary according to specific needs and opportunities that would be identified through cooperative business, government, and labor production committees, committees that would in many ways borrow from the experiences of the agricultural sector.

Creation of national sectoral policies would differ significantly from traditional concepts of a planned economy. By the use of formal working groups from all affected parties—business, government, and labor—the focus of policy creation would be the creation of compacts that will provide guidance to actions that already would be taken, but that otherwise would be unfocused. Because of the size and complexity of the U.S. economy, creation of national sectoral policies by necessity would not directly involve every industry or economic activity. Rather, if business, labor, and government in a number of key economic activities such as housing, automobiles, biochemicals, apparel, and primary metals can cooperatively devise effective economic strategies, then the hundreds of other linked industries and economic activities will also benefit. Such a limited, but highly targeted, approach to bringing rationality to government's economic interventions and public/private cooperation is within the present management capacities of business, government, and labor.

There are a number of requisites for the creation of effective national sectoral policies including: an improved analytical capacity that will permit collection and analysis of better economic information; creation of a mechanism in the executive branch of the federal government (preferably in the Executive Office of the President) that would be responsible for initiating and evaluating national sectoral policies and coordinating them with fiscal, area development, monetary, trade, and regulatory policies; creation of improved consultative systems among and between the many federal agencies, the Congress, and the state and local governments; and creation of an effective consultative system with the private sector, both business and labor. Each industry has its own potential and its own problems that must be addressed systematically by those most intimately involved. The success of the agricultural sector in the United States illustrates the many benefits to be gained from focused cooperation between business, workers, and government.

Nonmetropolitan Development Capacities

The sweep and power of the changes underway in both the international and domestic economy are often beyond the development and remedial capacities of individual communities and individual nonmetropolitan communities. For example, there is little that Youngstown, Ohio, or even U.S. Steel, can do under present circumstances to alter the worldwide shifts underway in steel production. Too many factors are concerned and too many participants are involved.

Nonmetropolitan areas would be major beneficiaries of sectoral development approaches. Partially, these benefits would be derived from an improved national economy. Also, such benefits would accrue to nonmetropolitan areas because of the weak development capacities they now possess. Thus, targeting of public or private actions could minimize weaknesses and build on what strengths that do exist. For purposes of analysis of the capacities of nonmetropolitan areas to participate in national economic revitalization, a typology will be used as follows: (*a*) nonmetropolitan institutional and leadership capacity; (*b*) nonmetropolitan financial capacity; (*c*) nonmetro-

politan human resource capacity; and (*d*) nonmetropolitan physical capacity.

Institutional and Leadership Capacity

Nonmetropolitan areas are burdened with too many units of government. Although nonmetropolitan areas possess less than one-third of the nation's population, they have 85% of the 3,042 county governments, 70% of the 18,000 municipalities, 80% of the 16,000 townships and towns, 67% of the 26,000 local special districts and authorities, and 45% of the 2,000 sub-state multijurisdictional districts. This excessive number of governmental units creates complexities and administrative costs that are beyond nonmetropolitan capacities. Institutional consolidation seems unlikely in the foreseeable future.

Leadership for public sector development activities comes primarily through federal-sponsored programs such as the Farmers Home Administration, the Small Cities Program of the Department of Housing and Urban Development, and the Economic Development Administration. These programs provide funds for institutional building and direct technical assistance. However, these program activities possess only limited coordination at either the policy or program level. The funds provided through these programs for staff are limited—less than $100 thousand per program for a seven- or eight-county area. Planning activities are focused more toward the delivery of agency funds than overall development needs. Staff are given limited training. For example, the staff charged by the Department of Agriculture to conduct its nonmetropolitan development through more than 1,000 county offices is trained in agriculture as opposed to economic and community development.

Financial Capacity

Nonmetropolitan areas have inadequate access to public and private capital. Theoretically, capital markets are efficient. In reality they rarely are. These areas have limited financial resources for private sector investments, particularly for small business, reflecting the small size of nonmetropolitan financial institutions, and their lack of experience making nonagricultural business loans.

The diversity of size, numbers, and financial capacities of nonmetropolitan units of government, coupled with the generally lower per capita incomes, restricts the financial abilities of these areas to undertake many essential public activities, such as construction of community facilities.

Human Resource Capacities

Publicly sponsored training and vocational education programs are a major tool for improving the productivity of firms and the per capita incomes of individuals. Although substantial progress has been made in the construction of vocational facilities in nonmetropolitan areas, there is substantial evidence that these programs are little related to the economic development needs of the places they serve. Although some states, such as South Carolina and Oklahoma, have used vocational education as a means to increase nonmetropolitan investment and increase placement rates of the trainees, these programs are still the exception rather than the rule.

Physical Capacities

Nonmetropolitan areas traditionally have had limited public infrastructure. This has limited nonmetropolitan development. In response to this perceived need, a wide array of public programs has been created, such as the Rural Electric Administration, Farmers Home Administration Community Facilities Program, Economic Development Administration, Appalachian Regional Commission, Title V Commissions, and a variety of special purpose programs. In aggregate, these programs have substantially enhanced the physical development capacities on nonmetropolitan areas over their previous condition.

Yet, as the nation enters the 1980s, there is growing evidence that even with these prior investments increases in population and the expansion of public regulatory requirements have created conditions whereby the physical plants of nonmetropolitan areas are increasingly inadequate for either community development or economic development needs. The Department of Commerce, in *A Study of the Public Works Investment in the United States,* has documented that in terms of real purchasing power the United States is now investing less in public works than in the 1960s, approximately 30% less. Although this can be explained in part by completion of the original

interstate highway system and declining demands in education, the declining levels of investments are prevalent in real terms even when these two items are excluded. If there is a relationship between private investment and public works, this decline in public infrastructure investments may have long-term negative consequences.

A series of studies by the Economic Development Administration also have documented how many of those public works investments made for development purposes are unused. Specifically, EDA has found that less than 25% of its industrial park investments are being utilized. This represents a substantial diversion of limited public infrastructure investments to nonproductive uses. The EDA example is a paradigm for other programs found through the federal, state, and local levels of government.

Strengthening Nonmetropolitan Development through Sectoral Policies

Sectoral policies would permit the focusing of the limited area development assistance that is available to nonmetropolitan areas. Specifically:

The creation of a common logic for economic revitalization will permit the many units of local, state, and federal government to focus their policies and programs on key actions. Such targeting can do much to limit the present chaos found in economic interventions by multiple agencies.

The creation of sectoral policies will permit better identification of capital gaps existing in nonmetropolitan areas. Such identification would in turn permit existing federal financial programs, such as the FmHA Business and Industrial Loan Program, Small Business Administration, and EDA Title II Business Loan Program to better assess aggregate needs and better allocate the credit they do control.

The creation of sectoral policies will assist nonmetropolitan areas to identify and implement training programs that can improve placement of trainees and attract private investment. Such policies can provide a conceptual framework for a number of needed reforms in the nation's nonmetropolitan training and vocational education programs. (*a*) There should be an improvement of data and information systems to identify specific training demands/supplies by geographic area, skills, and time frames. (*b*) Improvement of polic and administrative structures that administe training and vocational education programs including improved local involvement, i needed. (For example, metropolitan area now are given autonomy in the administratio of CETA funds, while nonmetropolitan are programs are closely controlled by state gov ernments.) Finally, (*c*) there should be im provement in the links between training an vocational education and potential employers

The creation of sectoral policies can serv to better target public works investments. I an era of increasingly scarce public resource and declining real levels of public work funds, nonproductive investments must b avoided. National, state, and local sector policies will permit the targeting of publi works to those activities that have a highe probability of enhancing the community itse as well as its economic development.

Conclusion

For the foreseeable future, America face many changes—some will be disruptive an some will be opportunities for growth. Th success of business, labor, and government i minimizing the negative consequences change and in seizing new opportunities wi largely determine the economic and comm nity development fate of the nation and i nonmetropolitan areas.

References

Advisory Commission on Intergovernmental Relatio "A Discussion Paper on Balanced Natio Growth." Presented at the Conference on Balanc National Growth and Economic Development, Wa ington, D.C., Feb. 1978.

Braden, Paul, ed. *Human Resources and Regional Dev opment*. U.S. Department of Commerce, Econon Development Administration, Washington, D. 1979.

Executive Office of the President. *Economic Report of President, 1980, Summary*. Washington, D.C., 19

Schwartz, Gail Garfield, and Pat Choate. *Revitalizing U.S. Economy: A Brief for National Sectoral P cies*. Columbus, Ohio: Academy for Contempor Problems, Jan. 1980.

U.S. Department of Commerce. *A Study of Public Wo Investment in the United States*. Washington, D. Apr. 1980.

U.S. Department of Commerce, Bureau of the Cens *Statistical Abstract of the United States, 1979*. Wa ington, D.C., 1979.

Social Science Contributions to Rural Development Policy in the 1980s

Kenneth L. Deavers

Because it will help to frame the subsequent discussion in this paper, let me begin by defining rural development policy. As I see it, rural development policy involves deliberate action by federal, state, and local governments and private institutions and individuals to achieve three goals: (*a*) improved rural income levels and employment opportunities; (*b*) improved access by rural residents to adequate housing and essential community facilities and services; and (*c*) responsible use of rural resources and the rural environment to preserve the quality of rural life.

In attempting to achieve these rural development goals, federal policy needs to be guided by some set of implementation principles. As enunciated by the current administration, these principles include: (*a*) recognizing the diversity of rural areas and providing continuing opportunities for individuals to choose among a wide range of rural lifestyles; (*b*) achieving an equitable distribution of opportunities, primarily through targeting action on distressed rural areas, communities, and people; (*c*) increasing the planning, management, and decision-making capacity among public (and private) institutions concerned with economic opportunity and quality of life in rural America; (*d*) implementing federal actions in a way that recognizes local priorities and coordinates federal, state, and local rural development spending; and (*e*) providing delivery mechanisms that make programs more accessible to rural governments, community-based organizations, and citizens. Rural policies and programs undertaken in this context provide the funds for and mechanisms of rural development.

National Issues and Rural Development Policy

One key to shaping federal rural development policy in the 1980s will be an improved understanding of the linkages between national issues and trends, and rural economic and social conditions. The social sciences can contribute to this understanding through research and analysis focused on significant national issues and their rural policy consequences. Obviously, there will be a somewhat different list of significant issues relevant to different policy spheres. For rural development policy, the test of relevance is that there be differential effects on rural areas and/or that public policies to deal with problems be different for rural areas. One example is energy.

Energy

Rapidly rising relative prices of energy and efforts to develop domestic energy resources are the two characteristics of the energy situation likely to be significant to rural areas in the 1980s. (Absent a major U.S. foreign policy failure, or government mismanagement of energy pricing, I do not believe that "shortages" will be important.) How will rising energy prices affect rural development?

I do not think we really know very much about the role of energy prices in shaping the overall spatial distribution of economic activity and population, other than to observe that the current situation occurred during a period of stable or falling relative prices of energy. Improvements in the highway transportation system clearly played a role in facilitating the decentralization of manufacturing activity, in the growth of the rural recreation industry, and in the deconcentration of population—and rising energy prices have contributed to a rapid increase in the relative price of transportation (especially for freight). But, are transportation costs a pivotal factor in any of these trends?

I think it is likely that the effect of rising energy prices will be significant for only a few rural industries, and that the major adjustments will be confined to a relatively small

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number of rural areas—leaving the general distribution of economic activity and people largely unchanged. Whether that overall assessment is correct or not, we can, I believe, identify some kinds of rural areas that are particularly vulnerable and begin to address the public policy issues involved in their adjustment to higher energy prices.

For example, throughout the High Plains of Nebraska, Colorado, Kansas, New Mexico, Texas, and Oklahoma where irrigated agriculture is prevalent, concern has been expressed about the long-term viability of that kind of agriculture. Falling groundwater levels have contributed to a gradual rise in irrigation costs (and potential absolute shortage of water), but rising energy prices have compounded the problem by greatly increasing the rate of increase of irrigation costs. It seems likely, in the absence of public policy intervention to subsidize continued production of current crops, that these areas will return to dryland farming—much more rapidly than availability and cost of water alone would have dictated. What kinds of adjustments does this imply for the farm owners directly affected, and for the region's rural communities? What are the costs and benefits of various policies to prevent or facilitate such adjustments, and how are these costs and benefits distributed among individuals, communities, and over time? It seems to me that answers to such questions are well within the state-of-the-art of the social sciences, that they require the skills not just of economists, but demographers, and rural sociologists as well, and that they would contribute to better public policy.

Research on the social and economic impacts of energy development in rural areas, especially in the Northern Great Plains, has identified a number of policy issues likely to grow in importance during the 1980s. Among the most significant of these issues is that of "mitigation strategies;" that is, the set of public policies aimed at avoiding socially disruptive and wasteful boom and bust cycles in energy-impacted communities. It seems reasonably clear from current research (and growing experience) that the construction phase of new mines, thermo-generators, and synthetic fuel plants stimulates considerably larger population, employment, and income growth locally than are sustainable in the long run. To accommodate this growth requires significant additions to the stock of local public capital. One question is how to provide for this peak demand without providing excess capacity which rural communities will not need in a few years and which locally generated public revenue may be unable to support. A second question is how various community relationships respond to growth stresses and how adverse distributional effects can be avoided in our quest for domestic energy.

Renewed Rural Growth and Changing Settlement Patterns

Perhaps the most important national trend for rural areas in the 1970s has been the rural population turnaround. From 1960–70, 3 million more people left nonmetropolitan areas than moved into them. By 1978, the net movement between metropolitan and nonmetropolitan areas was again nearly 3 million, but in the opposite direction. Reduced outmovement from farms, increased rural mining, manufacturing, and service employment, increased rural retirement, longer-distance job commuting, and a strong residential preference for rural/small town living have all contributed to this trend. The speed, persistence, and widespread nature of the trend have surprised nearly everyone.

As the map of nonmetropolitan population change since 1970 (fig. 1) shows clearly, rural population growth has not been uniform. In fact, nearly 350 nonmetro counties have grown at three times the rate of the United States as a whole. At the same time, there are more than 500 nonmetropolitan counties declining in population. For many of these places, the adjustment to decline is a continuation of a decades-long process. For more than twenty years we have thought about rural development policy primarily as a response to population decline and economic stagnation. But, it is becoming clear that rapid unanticipated growth also can create problems for rural areas. In both cases, local institutions are called upon to adapt to the changing size and composition of the community's population and economic base. In some ways, adjustment to growth may be more difficult because traditional community values and individual lifestyles may experience the most significant strains.

Thus, rural growth is a possible new focus for rural policy in the 80s. In my judgment, social science research and analysis can play an important role in determining whether such

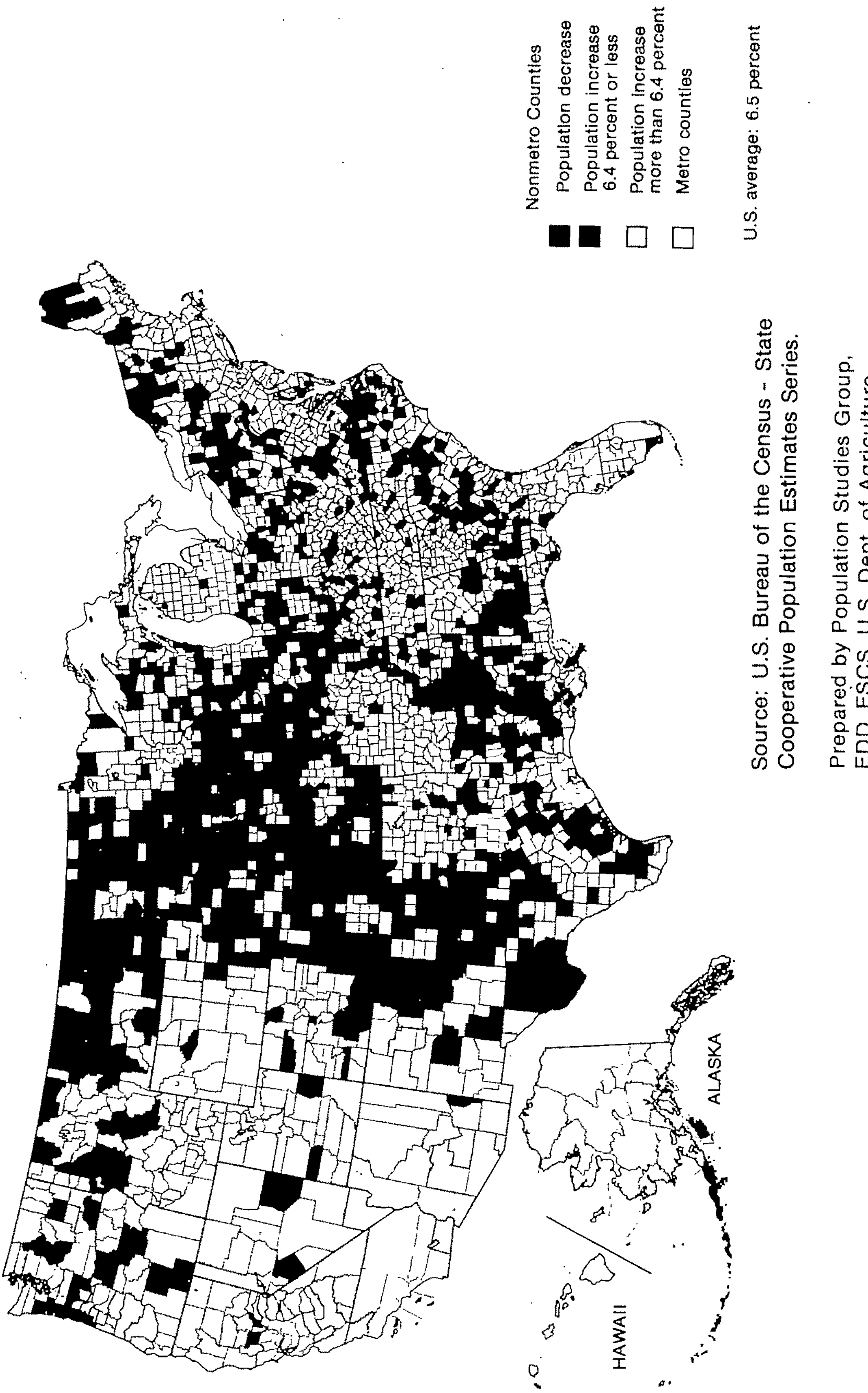

Figure 1. Population change for nonmetro counties, 1970–77

a focus for policy develops. In order for that to happen, I believe that considerably more attention needs to be given to analysis of the causes and consequences of rural population turnaround than to its description. This task should be among the highest priority research tasks once the 1980 census of population and housing becomes available.

Associated with that task, of course, is more social science research aimed at increasing our understanding of the causes and consequences of renewed rural growth and some assessment of the likelihood that it will continue in the 1980s—if so, where, and on what scale? Rural development policy appropriate to the 1980s will be difficult to formulate in the absence of such research knowledge.

Targeting Assistance on Unique Rural Problems

In the past two decades, rural lifestyles have changed—so much so, that the uniqueness of rural communities for policy purposes may have weakened significantly. Considerable fragmentary evidence for this assertion is available. For example, per capita personal income levels in rural areas have risen to 80% of those in urban; adjusting for cost-of-living differences probably would eliminate much of this remaining discrepancy. Rural residents also work at a wide-ranging set of activities similar to those of urban Americans. In March of 1975, manufacturing, wholesale and retail trade, and services, each had roughly 20% of rural employment, while agriculture had less than 10%. There is no longer any significant difference in infant mortality rates between urban and rural areas, and substandard rural housing has declined from 59% only twenty-five years ago to less than 7% today. But these comparisons of aggregate or average conditions in rural and urban areas obscure important differences. Two of these differences seem to me to be of particular policy significance. In each case, I believe that the social sciences have failed to marshall evidence effective to shape rural policy (although, perhaps, the failures have been for different reasons).

Rural Poverty

Poverty continues to be a serious problem for many rural Americans. However, because rural poverty is often scattered and hard to se (and may even appear "picturesque" to casual observer), the public perceives povert in 1980 as a largely urban phenomenon. Nevertheless, the roughly 9 million rural poor con stitute 34% of the nation's total poor.

Poverty is not uniformly distributed in rura America. Because of the residence patterns o rural minorities, and historic U.S. economi development patterns, rural poverty is heavil concentrated in the South. Nearly two-third of the rural poor live in that region, where ove 20% of the rural population failed to earn in comes above the poverty level in 1975. Th incidence of Southern rural poverty is like tha in many large Northern cities; e.g., Detroit Chicago, Boston, and Baltimore. As evidenc of the chronic and persistent nature of Southern rural poverty, 237 of the 255 counties tha have fallen into the lowest 20% of rural coun ties by income rank in each decade since 195 are located in that region.

Rural poverty differs from that in urba areas in some fairly fundamental and impor tant ways. At the community level, where lo personal and family income are so endemic a to be reflected in area-wide data, the ru poor often are located in environments whic lack adequate human and community fa cilities, which are isolated from other area with such facilities, which lack a wide range o employment opportunities, and where institu tional capacity—particularly governmental— is unable or unwilling to provide support. Fo individuals and families, rural poverty is ofte not the result of unemployment. Rather, it re sults from the types of jobs available in rur labor markets, a lack of appropriate skills an training for better jobs, a lack of transporta tion access to take advantage of opportunitie and chronically poor health.

For many of the rural poor, especially chronically disadvantaged areas of the Sout welfare reform is a key element of federal rur policy. Welfare reform proposals considere in recent years would have established na tional minimum payment standards, mad numerous changes in asset qualification re quirements, and changed participation re quirements related to family status and lab market status that would have benefited rur residents. While not strictly a developme policy, no expansion of traditional econom development programs would have as imme diate and obvious consequences for the we being of the rural poor—in terms of their ab

ity to obtain the food and services essential to a decent level-of-living—as welfare reform.

Rural Isolation

There is good reason to believe that Americans view rural communities as providing a lifestyle worth preserving. Residential preference research has shown consistently that a significant segment of the population would prefer to live in smaller cities, towns, or rural areas. The changed geographic distribution of economic activity favoring more rural locations, combined with a preference for living in such places, makes it likely that the 1980s will provide opportunities for many people to realize their lifestyle preference and an acceptable standard of living. But rural life is increasingly complex and diverse, and for some rural areas distance and scale are a significant impediment to improved conditions.

The basic character of dispersed rural populations is that they do not have as wide a range or high a level of facilities and services as city people. The extent to which this is true varies widely. There is a class of counties that have no town of 10,000 population and that are not readily and inexpensively convenient to either the larger nonmetro cities or to metropolitan centers. These mostly rural and remote counties are largely in the West (but not the Pacific Coast). However, smaller groups of them are found in the Ozarks, the Southern Appalachians, and the Upper Great Lakes. About 600 counties with a population of approximately 6 million are in this group. At the extreme are a number of settled areas in the Plains, the Great Basin Country, and Alaska that lie more than 100 miles from the nearest place of 10,000 people.

Overcoming the disadvantages of physical isolation and low population density are a major and unique part of rural development policy. The application of new forms of organization and technology—transportation, communication, and telecommunication—can contribute to alleviating conditions of isolation. Furthermore, federal assistance may help to make available the skills, experience, and fiscal resources necessary to deliver services to a low density population. What seems likely to happen, in the absence of effective social science contributions to research on this topic, is the application of (or even federal requirements for) urban-based, capital-intensive technologies. In the process we may end up destroying rural forms of settlement and their capacity to provide unique kinds of lifestyles.

Public Policy and Social Science Research

Public policy responses to a social issue can take several forms ranging from no action, relatively simple change in the rules and procedures of current programs, to legislative initiatives creating new agencies and programs. One can argue that the level of policy response will (and should) be related to the perceived political and substantive importance of the issue. In addition, there is an essential time dimension. For example, one reason public policy has not yet responded to the rural population turnaround with new legislation and programs is its relative newness. This newness affects both the perceived political salience of the turnaround and understanding of the substantive issues it raises.

There is, of course, no guarantee that the results of social science research will be influential in shaping policy. The relationship between research and policy is tenuous. Policy makers do not always understand how to use the results of research, in part because research fails to indicate what policy choices are available, and who will benefit or lose from particular choices. For example, most research monitoring rural population trends in the 1970s has paid only passing interest to the potential implications of these trends. Thus, it is difficult for policy makers to judge the costs and benefits of the turnaround, or to anticipate its impact in different areas and for different population groups. Moreover, very little research has focused on the process through which population change impacts on community structure—which institutions are involved, what is the timing of impacts vis-à-vis the initial population growth, how are the impacts distributed throughout the community? Yet, these are the issues which can give population turnaround political salience as an issue, and which can shape the public policy response.

Researchers need to know how, where, and when one gains entry to the policy process. They need to understand that many groups are involved—the White House, executive branch agencies, Congress, governors, mayors, and private interest groups. As a consequence,

there are many options—local, regional, state, and national—for building bridges between their work and the policy making process. In addition, research results need to be disseminated to policy makers in a useful and understandable way. Without more effective communication, there is little chance that the knowledge gained from social science research will contribute to rural policy in the 1980s.

Prospects for Rural Development Delivery Strategies and Programs in the 1980s

John M. Cornman

Obviously, predicting the future of any endeavor involving politics is risky, particularly when the assignment is to look a decade ahead. However, the assignment is not unattractive. There is little need for copious foothoting, and the chances are slim that anyone will check these predictions in ten years. Even so, it would seem prudent to establish several definitions.

Development encompasses economic de-/elopment, access to services and public 'acilities, stewardship of natural resources, ınd the enhancement of the environment. It ılso includes the process of increasing the ca-)acities of rural people and the institutions which serve them to identify problems, establish goals, set priorities, and devise, select, ınd carry out strategies to attain those goals.

Economic development encompasses the ıvailability of jobs, the closing of gaps in in-;ome and wealth, and the creation of diverse, esilient local economies. Thus, extraction of nineral ore, which creates a boom and bust ycle, may represent economic growth in the arly stages; but it may not achieve stable,)ng-term economic development. Rural de-'elopment also concerns agriculture and other ital efforts.

A development policy consists of goals, ac-on or funding programs, and the process or elivery strategies which join the two.

Finally, development goals for jobs, inbme, services, facilities, health, and others re, for the most part, the same for both rural nd urban areas. Different delivery strategies nd variations in program designs are re-uired, however, to achieve goals within those vo areas.

The prospects addressed in this paper re-ect the view that what is needed is not an rban versus rural development policy, but ıther a national development policy with de-very strategies and programs appropriate to urban or rural areas. Such a policy would allow one to muse about prospects for the whole policy as well as the rural elements of that policy. The prospects of both will be affected, if not determined, by international, national, and rural issues, the resolutions of which I am no better prepared to predict than I am to predict the future of strategies and programs, themselves. I do not pretend this list of issues is complete or that I have included all the implications of these issues and their ramifications for development in rural areas.

International Issues

The overriding international concern is peace, or, perhaps more accurately, the degree of peace present over the next decade. A convincing case can be made that the demand for food and nonfarm manpower needs of World War II were major factors in speeding the mechanization of farm operations, a decline in farm jobs and a rural-to-urban migration. Similarly, international confrontations consume resources, and agendas that involve long-term commitments, such as development, do not receive high priority. And, of course, if the confrontation were nuclear, all issues other than survival become moot.

How the United States uses its agricultural capacity and expertise in international affairs will be another major factor in the coming decade. Will we choose to export food to balance our oil deficit or our expertise to help nations meet their own needs—or, more accurately, what blend of those choices will we pursue? Equally important will be the method chosen to implement the selected strategies. If, for example, a chosen strategy demands greatly increased production of certain commodities, implementation of the strategy could emphasize research, resources, and/or policies that ignore broader concerns of rural development.

Another international issue which will affect

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rural development is trade agreements. There is evidence that trade agreements that encourage low-wage industries abroad may succeed at the expense of low-wage industries in domestic rural areas, a traditional way of bringing industries to our rural communities. To offset this, however, the next decade may provide new export opportunities for rural enterprises.

Paramount among international trade issues are those affecting oil. These will affect not only our domestic policies but also our foreign policies and world peace.

National Issues

The list of national issues affecting prospects for rural development begins (or ends, depending at what part of the cycle you begin) with the extent of the nation's commitment to national development goals. Little progress will be made concerning employment, housing, or health problems in rural areas unless there is a commitment to address these issues nationally. Even if such a commitment exists, efforts will continue to be focused on urban areas unless there is broader understanding and acceptance that the nation has a stake in rural development. That stake includes meeting society's responsibility to the poor, ten million of whom live in rural areas; meeting national goals such as those concerning employment, housing, health, and energy; creating the jobs and markets needed for a viable national economy; and providing job and residential options necessary to the well-being of a free society.

The degree of commitment will be influenced by the degree of inflation and the degree of faith (well placed or not) in the impact of a balanced national budget.

The ability to deliver on the commitment will be affected by the impacts of energy policies (including cost and availability) and new technology on rural development opportunities, and our willingness and ability to relate macrolevel policies and microlevel programs more effectively in the future than in the past.

Will the energy crisis work for or against location of manufacturing and service jobs in rural areas? Will it help or hinder dispersion of food-processing facilities? Will it help or hinder rural residents commuting long distances to jobs? Will new technology encourage dispersion or concentration of jobs and facilities and will it serve smaller-scale enterprises and communities as well as larger ones? Will we learn how to transfer the benefits of this technology to meet rural needs? Will we remember the importance of smaller-scale enterprises as we debate the reindustrialization of the nation?

Obviously, the migrations caused by all of the above will affect prospects for rural programs in the decade ahead. Will "reverse" migration continue? Who will be moving? How well will we understand what is happening and who is benefiting?

Prospects on the national level also will be influenced by the outcome of presidential and congressional elections. A president committed to rural development can help make up for the lack of an organized constituency, and members of Congress who look beyond special interests can provide needed leadership.

Rural Issues

Certain rural issues are critical to prospects for rural development policies. A better understanding of the diversity of rural areas; an adequate data base; increasing the capacities of rural people and the institutions which serve them; organizing to influence governments, and public and private sector investment decisions; selecting leaders committed to development—all will be vital to rural development in the decade coming.

Rural areas differ geographically, ethnically, and by virtue of population size, level of development, and degree of poverty. Rural people and those working on their behalf must understand the need for flexible development strategies that can respond to that diversity. Too often, rural advocates as well as national-level policy makers are insensitive to this diversity.

The inadequacy of an adequate rural data base is both a serious barrier and a convenient excuse. Too little is known about the extent of poverty, unemployment, and underemployment in rural areas; about who is moving where for what reasons; about the impact of fewer farms on the quality of life in rural communities; about the costs of delivering services in rural areas; about the quality of education in rural schools. There is a need to identify data gaps and improve current data

collection efforts in rural areas. New data collection efforts should include program documentation and evaluation as well as the gathering of statistics.

A growing recognition of the need for such data is an encouraging sign. So is the acknowledgement that development requires the support of permanent institutions to deliver services and assist with capacity building (increasing the capacity of rural people and their institutions to identify problems and set and attain goals). This represents an important departure from the recent past.

For most of the past two decades efforts to nclude those omitted from the development process focused on guaranteeing certain rights and securing more equitable distribution of public resources. I think history will show hat, as an initial effort, the focus was correct. We will be hard pressed to come up with a ural development act for the South as effecive as the 1964 Voting Rights Act. That act lealt with a permanent (I trust) institution: the ormal procedure through which citizens elect leaders and influence policy. However, nany other efforts concentrated on establishng new organizations to deliver services and nfluence various levels of government. As a esult, we have a plethora of citizen-based organizations, coordinating committees, reional commissions, lobby groups, and cauuses, concerned with aspects of developnent. Many of these entities have been establshed to compete with existing, but nonreponsive, institutions. Whatever the merits of uch a strategy, it has yet to deal with two rucial elements—permanency and intellecual base. Forced to live on grants, many of hese organizations have had to trim sail or hange course in response to the grantsmanhip process. Many of the grant makers have ad no coherent or consistent development rategy to guide their decisions. Neither has hought been given to providing these organiations with the information required to roaden their perspectives.

What is involved is a fundamental change om a confrontation strategy to a developental strategy. With a shrinking, or at best atic, public grants budget, people interested development find these organizations serely limited in funds and expertise to make e change. At the same time, many of the ermanent institutions which could be importnt to development in rural areas—the land ant universities, community colleges, planning districts, and traditional citizen groups—have not grown to fill the gaps.

Recognizing that development takes time, patience, and commitment, it is becoming clear that the absence of permanent, responsive institutions with long-term commitments to rural development is a serious barrier.

And finally, to complete this list of factors affecting prospects for rural development in the 1980s is the ability of rural people, with all their diversity, to organize effectively and make themselves heard. Rural people, dispersed, diffuse and relatively few in numbers, frequently are ill-equipped to compete in the national arena for attention and resources, a cause of many of the barriers discussed above.

Given the historic inability of rural people to organize effectively around development issues on a national basis, and given the array of imponderables which could adversely affect rural development, it would be prudent to predict that there are no prospects for any new major, federal rural development programs or delivery strategies in the 1980s.

However, being something of an optimist, I do not believe the picture need be entirely bleak, if rural development advocates are willing to settle for a limited number of important advances and if the research community is willing to address rural development issues in ways useful to policy makers. Given a degree of cooperation between those two worlds, important advances could be made in the quality and quantity of data collected and disseminated; in understanding what is meant by capacity building and how to deliver what, to whom and when; in learning how to link various development programs for maximum impact; in encouraging the use of small business development as a tool to create new jobs; and perhaps in creating a broader development constituency around these issues.

These advances can be justified in ways consistent with what appears to be the political mood of the decade. Improved information could help program managers make better use of resources under their control. If the data collected involved the private as well as public sectors, the data could be used as a basis for improved private-public sector cooperation. Further, if encouragement of small businesses turns out to be a useful way to create new jobs, efforts in the area could attract the support of a wide range of interests—starting with small business and full employment constituencies, but extending to constituencies

concerned with development in general, civil rights, tax reform, small farms, conservation, and economic concentration.

Finally, I can predict that if progress is made along these limited fronts in the 1980s, then prospects for rural policies in the 1990s will be greatly enhanced, depending of course on war, peace, energy, agriculture. . . .

Rural Development: A Critique

Barbara J. Redman

The philosopher George Santayana once said that "those who cannot remember the past are condemned to repeat it." In order to know the present and future of rural development, one must know its past. In particular, it is necessary to know what has been wrong in the past if one is to know how to improve in the future.

All the other papers in this session are very similar. All identified broad goals of rural development, issues which in the coming decade should affect rural development, and suggestions for the future in policies and areas of research. None paused to reflect on the past, whether of institutional programs or academic research. None identified correctible errors or appraised the system's overall worth and effectiveness, in spite of widespread opinion (for example, Schaller 1978) that the history of rural development programs has been something less than an unqualified success story. It has thus been left to this paper to undertake the critical analysis, which given page constraints will focus on the academic literature.

What Has Gone Wrong?

Practicing economists will no doubt accept on faith the proposition that economic theory is an appropriate tool to use, although this assumption can be questioned. (Berry, for example, believes that ecology rather than economics is the most relevant discipline.) Given this assumption, economic analysis must always specify first, the arguments in the objective function, and second, some means of measuring or quantifying those arguments. This paper contends that researchers in rural development analysis have erred in each of these basic specifications.

Arguments in the Objective Function

As Deavers states, the goal of rural development should be to improve rural well-being and quality of life. However, in defining these terms, economists have almost always emphasized traditional economic concepts, such as level of per capita income, economic growth, and technical efficiency of operation, and ignored the subjective, noneconomic elements.

As a fairly representative example, consider the 1976 AAEA invited papers session on rural development. Edwards cited five bases for regional growth: increasing resource availabilities, advancing technology, expanding markets, conquering space, and building institutions. The only mention of human involvement is of population as a factor of production. Jansma and Goode merely assumed an upward sloping labor supply curve and then made it operational. Morgan emphasized the necessity of studying community decision-making processes, citing as proof the frequently impassible gap between researchers and community leaders, but one is left with the impression that he would like to be able to manipulate community decisions to agree with the researchers' policy proposals. Sorensen and Hartman, from a philosophical and sociological perspective, lamented the loss of sense of community in rural America which they believe is a result of centralized organizational structures. They criticized economic research for its emphasis on control of variables and faulted the social system and the disciplinary training of researchers for the fact that "no longer is primary attention given to determining the needs of people or to measuring the effectiveness in meeting those needs" (p. 935). A few years earlier Bawden's invited address on "The Neglected Human Factor" had merely pointed out the need to consider who will benefit from a program and the fact that average measures of income do not reflect inequalities; he acknowledged neither human involvement nor the possibility of goals other than income and employment.

These papers implicitly assume that income is a suitable proxy for quality of life. However, quality of life is not equivalent to income, much less to aggregate income without regard

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to its distribution. Poverty programs which dictate how government aid should be used have frequently "failed" in their objectives because the social worker's utility function is not the same as the welfare recipient's utility function. Government planners should have paid more attention to the indifference-curve analysis of matching versus unconditional grants.

The psychological and social needs and values of a community should be considered, especially the needs the community, not the planner, feels are important. (There are, to be sure, problems of establishing a community utility function.) Not all communities have the same values; studies show not only that rural values differ from urban values, but that farm values differ from rural nonfarm values (Larson). In addition to pointing out the need for individual community analysis, this demonstrates that as the rural nonfarm sector becomes more important (Beale), the equation of rural development policy with farm policy which has often been made in the past becomes more and more tenuous.

The importance of human values becomes especially evident when economically feasible new programs are introduced. For example, a county whose citizens voted to go legally dry may not welcome the advent of a distillery. One need not go to such an extreme example; cases frequently arise where a value for a quiet small-town existence is strong enough to veto industrial development. In his discussion of the implications of the rural population turnaround, Deavers mentioned that traditional community values and individual lifestyles can pose problems for adjustment to economic growth. In the development of its farm policies and programs, Congress has often been confronted with the conflict between values associated with small family farms and the greater efficiency thought to be associated with large-scale commercial operations. Given such values, researchers should realize that pursuit of the objective of rural development by economic measures need not maximize community satisfaction and may even decrease it. For example, the majority of rural white male suicides are those who have urban-oriented occupations and attitudes (Segal). Neither should researchers disparage the community if it rejects their advice (Sorensen and Hartman).

Harman, Eidman, Hatch, and Claypool, in a positive step, attempted to determine which among eight possible goals had highest and lowest priority for farmers, by the method of paired comparisons. This type of investigation, both in its purpose and in its methodology borrowed from psychology, should be encouraged as a check on whether economic research is seeking to maximize the proper objectives.

The importance of community attitudes to the success of a program has been demonstrated in the rural programs of the National Institute of Mental Health (Segal). Mental health is a particularly touchy area, because of age-old prejudice against the mentally ill and the stigma that is often attached to those utilizing mental health services. The success of these services is thus directly related to the attitude of the rural population toward mental illness and mental health services. Fortunately for its programs, the NIMH received encouraging responses in its preliminary surveys of attitudes. These attitudes also have become more positive in recent years.

Another area in which values affect economic performance is that of religious outlook. For example, Weller found that the people of Eastern Kentucky carry strong values for traditionalism, individualism, fatalism, immediate as opposed to long-term action, stoicism, and personal as opposed to object relationships. These values, but especially those of traditionalism and fatalism, impede implementation of many rural development programs. Redman has demonstrated (1979, 1980) that the area's religious history not only implies these personal characteristics which, according to Weller, then affect regional development, but that conservative versus liberal religious outlook affects the time and money an individual devotes to religious relative to secular market activities. The effort devoted to secular market activities is directly related to effort devoted to economic improvement.

In addition to having preferences among two or more goals, the community will perceive costs to each. These costs need not be identical with monetary costs. Morgan and Deaton investigated the psychic costs to workers of employment in a particular city, and concluded that migration did not always respond to monetary wage differentials. The psychic costs were significantly related to family earned income and satisfaction with social relationships. Satisfaction with new social and physical surroundings was more impor-

nt than satisfaction with work in the city for e successful adjustment of rural-to-urban igrants (Deaton, Morgan, and Anschel), hich again indicates the need to consider oneconomic factors. Schaller (1972) recogized that a tradeoff often exists in practice etween the possibilities of improving ecoomic versus noneconomic well-being. The ommunity must then choose between them, ased on its preferences. The rural population urnaround and the increased congruence of ocation with original preference of lifestyle, in pite of the general belief that urban areas ffer greater economic well-being (Dillman), uggests that noneconomic well-being carries ncreasing weight in locational decisions. eavers is concerned with maintaining the pportunity for choice among a variety of ural lifestyles. This is a refreshing and valuble focus in research and policy formulation, nd should be continued.

One further point concerns an input into the conomic development program, the develpment of people. Traditionally, economists ave dealt with the use and augmentation of hysical resources. In rural development especially, human resources must have at least qual importance. Economists have in recent ears begun to estimate the effects of education and physical and mental health on human apital and therefore on income and productivy (for example, Fein, Levine and Levine). s Cornman suggests, health and education re national policy goals which for rural areas ay need particular delivery strategies. Some fforts in this direction have been made, such s Daberkow and King's study of emergency edical service; these efforts should be connued.

uantification of Arguments

conomists have also often used biased estiates of even the traditional economic varibles. Consider as examples the frequently sed concepts of efficiency in farming and rofitability as an indicator of efficiency. Agcultural economists have often pointed to the crease in farm output per labor hour emloyed in farming as an indicator of increased rm efficiency. Even if one accepts this as an ppropriate concept (and Perelman questions because it is a measure of an average rather an marginal product), it is misleading in that does not include the nonfarm agribusiness sector which has greatly expanded in recent years. "Although only 4.5% of the U.S. population works on farms, another 5% is engaged in producing supplies, and another 10% is employed in processing the food and bringing it to the consumer" (Perelman, p. 66). The 4.5% presently employed on farms represents a steady decline from 30.1% in 1920 and 24.9% in 1930 (Perelman), but the inclusion of the expanding farm supply, processing, and distribution sectors considerably lessens the impact of these figures. If the total percentage of U.S. population in agriculture has declined, it has not declined by startling proportions. The real question is whether society has benefited by the replacement of farm labor by capital equipment. While mechanization has been the major emphasis of research, it also consumes much energy, with which society is only now beginning to be concerned. The question of effects of energy prices on factor combinations in farming and manufacturing industries can be added to Cornman's question of effects on industry location in rural versus urban areas. Both carry implications for rural employment and income.

Profitability, too, can be deceptive; it often is used as an indication of efficiency. However, measures of profitability usually have not excluded the effects of government legislation. Tax shelters and loopholes and farm subsidies (as proportionate to farm sales) favor large farmers; pecuniary economies of scale exist in acquiring inputs and financial capital. Further, Hightower's by-now-famous critique of the land-grant university system indicates that agricultural research is designed to aid large farmers and agribusiness, not small farmers. Schaller (1978) holds that national farm policies overwhelmingly tend to be commercial-farm policies. The built-in advantages which large farms face in the American economic systems should lessen the conviction that profitability is necessarily proportionate to inherent technical efficiency.

While these criticisms refer primarily to rural farm development research, rural nonfarm development research also suffers from errors in quantification. A particular vulnerability of this type of research is selection of appropriate proxy variables. Unfamiliarity with the local culture as well as data limitations can result in inadequate or inappropriate proxies for the social and psychological benefits received from a program; for example, in one study the number of movies and

ballgames attended served as a measure of Southern Appalachian mountain recreation, human resource development, and cultural isolation (Smith, Wilkinson, Anschel).

What Has the Past Trend Implied for Human Satisfaction?

As the present system favors big farms, so does the trend. The number of farms has steadily decreased since 1930, and average farm acreage has steadily increased. Rural industry only recently has begun to have prominence. What effect does this trend have on rural development and human satisfaction?

The major observable effect, at least until recently, has been labor migration away from the farms and rural communities, motivated by employment opportunities. This trend has been mitigated by some recent government and industry efforts to locate more industry in rural areas, which raises the problem of possible clashes of values discussed above but which at the same time makes it easier for a person to choose a preferred rural lifestyle. Out-migration creates adjustment problems for ex-farm workers, who traditionally have received little or no help in retraining or relocation. Migration to the cities due merely to economic inability to stay on the farm or in the rural community generally does little to maximize the individual's utility function (Deaton, Morgan, Anschel).

Problems also may arise for those who remain, whether on the larger mechanized farms or in new industry. The Marxian analysis of alienation (Elliott) may provide some insight here. Marx's basic premise is that creative, purposeful work is an important differentiating quality of the human from the animal species, and a person thus finds self-fulfillment in productive activity. However, a person tends to objectify what he or she produces and in time comes to see the product as something not only alien but also as taking on an existence of its own and controlling the producer's life. A contemporary analogy would be a successful businessperson's complaint that he or she is on a treadmill and unable to get off. The more specialization and mechanization, the less fulfillment and the more alienation, because the worker is more distant from the product of labor and cannot take particular pride in its production. Because labor is part of the essence of being human, the individual also feels alienated from himself or herself an from the rest of humanity. Current findings o the lack of job satisfaction in assembly-lin types of jobs suggest that Marx's analysis o alienation has some relevance to job satisfac tion, which in turn relates to the individual' perception of own well-being and quality o life. This, however, may be classified as a addition to Cornman's list of national issue with implications for rural communities rathe than as a particularly rural issue.

Alienation and the counter-struggle to retai one's humanity have been recurrent themes i American culture in the last two decades. I addition to Marx's view, psychologists hav suggested other theories on what is distinc tively human about humans as a species. Fc Freud, it is the prolonged period of childhoo dependence and narcissism which is then ab ruptly attacked by the outside world; fc Fromm, it is the search for love; for Frank the search for meaning in life; for existen tialists, the anxiety created by the polarity c freedom and the finitude of choices which ca be made. Maslow's hierarchy of needs, whic has a highest need of self-actualization (sel fulfillment), bears some resemblance t Marx's analysis. While theories and te minologies vary, most psychologists agre that nonacknowledgement of any major part c a person's psyche is unhealthy for the persor Freud and Jung particularly emphasize this All this seems to suggest that the increasin specialization associated with increased siz of operation and increased mechanizatior with the resulting depersonalization of th work and the emphasis on only a few particu lar needs and skills, may not be best fo the humans involved in targeted developmer areas even if technical efficiency is best serve by it. Although a certain degree of alienatio cannot be avoided, it could perhaps be re duced by careful planning.

This returns to the earlier question of argu ments in the development objective functior The first part of this paper pointed out th need to respect the community's wishes an values if community satisfaction (and not th developer's satisfaction) is to be maximized psychology, which should be added to Dea vers' list of social sciences, has much to cor tribute in determination of preferences. Th second part of this paper called into questio the reliability of the conventional measurin concepts of the conventional arguments. Bu finally, even if one initially ignores the com

nunity utility function, one is forced by the onsequences of industrialization and expanion to acknowledge negative consequences to he humans involved. While in Marxian analyis this is inevitable in all capitalist society, ne could perhaps mitigate some of the effects f one made appropriate provision for human alues at the outset. This reinforces the first ontention that rural developers should place nore emphasis on the noneconomic values of heir clientele.

s Correction of Past Errors Worth the Effort?

'he above analysis has omitted one important uestion: Is the whole effort worthwhile? Schaler (1978) suggests that it is not at all clear how nuch of the improvement in the well-being of ural people over time is due to rural development policy and how much is due to national conomic conditions. For example, he proposes that the rural population turnaround has nly been enhanced by development programs nstead of caused by them. Other factors acilitating rural in-migration include social ecurity retirement payments, increasing rural wareness of urban problems, and more limed urban employment opportunities. If in ict it is largely coincidental that programs to ncourage industry location in rural areas apeared at the same time as the population turnround, why spend the taxpayers' money on iese programs?

Cornman's paper approaches this viewpoint recommending a national development poly with location-specific delivery programs ther than an urban versus rural development olicy. Either alternative would keep domes- development economists gainfully emoyed. No profession would advocate curilment of its own sphere of employment, and e certainly should not expect this of econoists, in spite of the economic arguments for locative efficiency. However, one can safely lvocate research to determine the most efctive focus of research activity. If national onomic conditions are indeed the critical ctors in rural well-being, one may still ask s did Smith, Wilkinson, and Anschel) hether alterations in the rural infrastructure ould enhance or retard transmission (and so, considering the current state of the econny, whether improved transmission is desirle). One also may extend the suggestions ade in the earlier part of this paper to naonal development policy.

It is, admittedly, more difficult to correct deficiencies than to continue as is. The methodological suggestions are particularly difficult to implement because they require much primary data and, for many researchers, a reorientation in thinking. If specific development programs are to be continued, however, these deficiencies must be remedied. Still open for research is the broader question of allocation of economists' and taxpayers' resources; that is, are rural development programs per se worth their expense?

References

Bawden, D. Lee. "The Neglected Human Factor." *Amer. J. Agr. Econ.* 55(1973):879–87.

Beale, Calvin. "People on the Land." *Rural U.S.A.: Persistence and Change*, ed. T. Ford, pp. 91–112. Ames: Iowa State University Press, 1978.

Berry, Wendell. "Where Cities and Farms Come Together." *Radical Agriculture*, ed. R. Merrill, pp. 14–25. New York: Harper & Row, Publishers, 1976.

Daberkow, S. G., and G. A. King. "Response Time and the Location of Emergency Medical Facilities in Rural Areas: A Case Study." *Amer. J. Agr. Econ.* 59(1977):467–77.

Deaton, Brady J., Larry C. Morgan, and Kurt Anschel. "The Influence of Psychic Costs on Human Resource Allocation." Paper presented at the AAEA meeting, San Diego, Calif., 21 Jul.–3 Aug. 1977.

Dillman, Don A. "Residential Preferences, Quality of Life, and the Population Turnaround." *Amer. J. Agr. Econ.* 61(1979):960–6.

Edwards, Clark. "The Political Economy of Rural Development: Theoretical Perspectives." *Amer. J. Agr. Econ.* 58(1976):914–21.

Elliott, John. "Continuity and Change in the Evolution of Marx's Theory of Alienation: From the *Manuscripts* through the *Grundrisse* to *Capital*." *Hist. Polit. Econ.* 11(1979):317–62.

Fein, Rashi. *Economics of Mental Illness*. New York: Basic Books, 1958.

Harman, Wyatte, Vernon R. Eidman, Roy E. Hatch, and P. L. Claypool. "Relating Farm and Operator Characteristics to Multiple Goals." *S. J. Agr. Econ.*, no. 1 (1972), pp. 215–20.

Hightower, Jim. *Hard Tomatoes, Hard Times: The Failure of the Land Grant College Complex*. Washington, D.C.: Agribusiness Accountability Project, 1972.

Jansma, J. Dean, and Frank M. Goode. "Rural Development Research: Conceptualizing and Measuring Key Concepts." *Amer. J. Agr. Econ.* 58(1976):922–27.

Larson, Olaf. "Values and Beliefs of Rural People." *Rural USA: Persistence and Change*, ed. T. Ford, pp. 91–112. Ames: Iowa State University Press, 1978.

Levine, Daniel, and Dianne Levine. *The Cost of Mental*

Illness—1971. Washington, D.C.: U.S. Department of Health, Education, and Welfare, Publication No. (ADM) 76-265, 1975.

Morgan, Larry C. "Analytical Institutional Economics and Rural Development Research: Opportunities for a New Synergism." *Amer. J. Agr. Econ.* 58(1976):928–32.

Morgan, Larry C., and Brady J. Deaton. "Psychic Costs and Factor Price Equalization." *S.J. Agr. Econ.*, no. 1(1975), pp. 233–8.

Perelman, Michael. "Efficiency in Agriculture: The Economics of Energy." *Radical Agriculture*, ed. R. Merrill, pp. 64–86. New York: Harper & Row, Publishers, 1976.

Redman, Barbara. "The Impact of Great Revival Religion on the Personal Characteristics of the Southern Appalachian People." Unpublished manuscript, 1979.

———. "An Economic Analysis of Religious Choice." *Rev. Religious Res.* 21(1980):330–42.

———. "Individual Production of Spiritual Goods." *J. Econ.* 6(1980):

Schaller, W. Neill. "Community and Rur Development—Implications for Economic Extensio Programs." *S.J. Agr. Econ.*, no 1 (1972), pp. 15–2

———. "Public Policy and Rural Social Change." *Rur USA: Persistence and Change*, ed. T. Ford, p 199–210. Ames: Iowa State University Press, 197

Segal, Julius, ed. *The Mental Health of Rural Americ* Washington, D.C.: U.S. Department of Health, Ed cation, and Welfare, Publication No. (HSM) 73-903 1973.

Smith, Eldon, J. Keith Wilkinson, and Kurt Ansche *Some Effects of Rural Road Improvement Appalachia—A Case Study in the Eastern Kentuc Coal Fields*. University of Kentucky Agr. Exp. St Res. Rep., May 1973.

Sorensen, Donald M., and L. M. Hartman. "Organiz tional and Institutional Aspects of Community: Som Conceptual Perspectives." *Amer. J. Agr. Eco* 58(1976):933–6.

Weller, Jack. *Yesterday's People*. Lexington: Universi Press of Kentucky, 1965.

The Role of Economic Analysis in Futures Market Regulation

Anne E. Peck

The history of regulation of commodity futures markets manifests persistent concern over "excessive speculation." The phrase is found repeatedly in the hearings leading to the earliest federal statute—the Grain Futures Act of 1922—and it reappears in each subsequent revision of the statute, including the two major ones, the Commodity Exchange Act of 1936 and the Commodity Futures Trading Act of 1974 (Cowing, Rainbolt). A substantial revision in the Commodity Exchange Act in 1968 was also largely an outgrowth of the notorious vegetable oil swindle of 1963. The phrase "excessive speculation" has not been defined, much less quantified, in the statutes, even though the phrase is used specifically to justify the creation of limits on speculative positions. The economic literature has recognized the need for and importance of speculation and even has provided evidence of speculative inadequacy as a chronic affliction of some futures markets (Gray 1960, 1967). A major effort to fill the definitional void was Working's construction of a speculative index (1960). Whereas the term "excessive" is employed in the pejorative sense in the congressional deliberations, Working simply undertook to use market statistics to describe the relationship between hedging and speculation. His research led to a measure, the speculative index, which reflects the extent by which the level of speculation exceeds the minimum necessary to absorb long and short hedging, recognizing that long and short hedging positions could not always be expected to offset each other even in markets where these positions were of comparable magnitudes. Speculation above the minimum defined by the index was not defined simultaneously as excessive. Indeed, in some markets whose performance is demonstrably hampered by speculative inadequacy, the level of speculation exceeds that minimum.

It is important in any effort to arrive at a definition of "excessive speculation" to keep market performance criteria in mind, and to distinguish between characteristic levels of speculation in different markets over time and episodic flurries of speculation in a particular market which may reflect underlying fundamentals but which may otherwise suggest price distortion or price manipulation. Market regulation, whether at the exchange or government level, is concerned with preventing abuses and has its focus upon particular episodes or crises. The economist, while remaining cognizant of the potential for abuse, needs to try to understand why levels of speculation vary so widely across markets as a continuing phenomenon, and how market performance may be related to such variation. As but one example, data presented in this paper will confirm that the pork belly futures market is much more speculative than the wheat futures market, yet speculative abuse (or the threat of abuse) has been charged several times in recent years in wheat futures and not in pork belly futures.

This paper does not directly address the questions of episodic market distortion or manipulation, although economic research has its bearing on these problems too. Rather, what is undertaken here is an assessment of the speculative character of selected markets with particular reference to the impact of changed hedging requirements upon the speculative component in recent years. The overall market performance issue will then be revisited in the context of the three wheat futures markets, and the caveat will be reiterated that less speculation does not make for better markets.

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Comments by Tom Hieronymus on an earlier paper stimulated the research reported here and comments by Roger Gray on an earlier version of this paper clarified these arguments. Their assistance is gratefully acknowledged.

Measures of Speculation on Eight Futures Markets

Estimates of speculation and hedging participation in most futures markets are available monthly from the Commodity Futures Trading Commission (CFTC) *Commitments of Traders* reports. There, participants are categorized, first, as large or small (reporting or nonreporting) traders, and then the positions of the large traders are identified as speculative, spreading, or hedging. The small traders are not further classified; hence, depending upon the relative size of this group, descriptions of the market based upon these data vary in accuracy. The data do reveal basic trends in market composition. In the major agricultural markets, reported hedging has grown much more rapidly than the growth in the total market activity. In the two decades prior to 1972, long hedging in the wheat markets accounted for 23% of the open interest, and short hedging accounted for 45%. Since 1972, short hedging averaged 61% of the open interest and long hedging was 65%. Similar growth in hedging use of futures market is apparent in the corn and soybean markets, and some evidence of the extent of changes in the composition of the open interest on these markets is provided by the data on reported hedging ("long" and "short") in table 1. An earlier paper describes the changes in market use evidenced by the numbers reported here in more detail and examines the relationship between hedging use and total market use (Peck).

Not only has the hedging component in these markets grown, but the balance between long and short hedging has become closer. Balanced long and short hedging might suggest that speculators are not needed in a market, long hedgers would offset the positions of short hedgers. One measure of the speculative character of a market uses this notion, being the speculation exceeding that required to offset any unbalanced hedging. With nearly balanced hedging, this measure would be infinitely large and would imply that markets are highly speculative. The difficulty with the net hedging concept is that individual hedgers are rarely so alike as to size and timing of their positions and as to specific delivery months to be used, that only occasionally will long and short hedging positions offset each other.

Illustration of the problem is provided in the commitments data by the separation of positions into those held in "old crop" and "other" futures. On 31 January 1978 (when "old" and "other" divide the wheat crop year and the total positions roughly in half), reporting hedgers in Chicago wheat held 110.0 million bushels long and 114.8 million bushels short, for a net short futures position of 4.8 million bushels. In this situation, minimum required speculation could be defined as a 4.8 million bushel long position. However, hedgers' positions in "old" crop futures (March and May options) were net short 7.9 million bushels and were net long 3.1 million bushels in the "other" options (July, September, and December). Thus, a measure of the speculative requirement of the 31 January 1978 Chicago wheat market ought to reflect that both long and short speculation was required to offset the net short position of hedgers.

As the balance becomes closer and the hedging component grows within a market's total composition, the likelihood of direct offset increases, but it remains uncertain. Working's speculative index (T), was constructed with the differing needs of long and short hedgers in mind. It was derived from the analysis of the relationship between long relative to short hedging and long speculation relative to short hedging. In effect, the index measures shifts in the relationship between these two variables, measuring the excess speculation over that required to offset both the long and short hedging on a market.

The difficulty in calculating Working's index, or any index, is that the positions of the small traders must be assigned as either speculative or hedging. As there is no one right way to make the assignment, two alternatives are used here. A common assumption in using these data is that most small traders are speculators. It is convenient to extend this assumption here to say that all small traders are speculators. This provides an upper bound estimate of the speculative index. A second estimate results from allocating the small positions as speculative or hedging. In a variant of the procedure suggested by Larson's work and developed by Rutledge, the distribution of hedging and speculative positions from the historic full market survey reports are used to classify the monthly, nonreporting data into its appropriate category.[1] As with Rutledge's re-

[1] Rutledge's method, when applied to current data, often resulted in negative hedging of speculative positions, reflecting the significant changes in market composition which have occurred since the period when the market surveys were taken. Rutledge'

Table 1. Measures of the Speculative Index, Position Limits and Hedging Balance on Selected Commodity Futures Markets

	Speculative index[b]			Reported hedging			
Commodity[a] Period	Lower bound	Upper bound	Position limit[c] (contracts)	Long	Short	Offset (% open interest)	Balance
All wheat							
1947–71	1.212 (0.151)	1.589 (0.344)	400 (1.6)	22.9	44.7	21.9	7.7
1972–77	1.040 (0.020)	1.178 (0.054)	400 (0.7)	61.1	64.6	57.7	40.6
Corn							
1948–71	1.263 (0.244)	1.609 (0.442)	400 (1.5)	23.9	46.6	22.2	9.1
1972–77	1.045 (0.017)	1.204 (0.051)	600 (0.6)	61.9	59.8	55.9	37.2
Soybeans							
1951–71	1.329 (0.245)	1.946 (0.608)	400 (1.2)	20.7	29.9	17.2	4.4
1972–77	1.061 (0.034)	1.310 (0.121)	600 (0.8)	42.2	42.0	37.2	20.5
Maine potatoes							
1952–74	1.856 (0.476)	2.923 (1.763)	350 (2.7)	7.7	33.4	7.7	0.5
Live cattle							
1971–77	1.568 (0.189)	2.173 (0.514)	n.a.	8.0	40.2	7.5	0.6
Pork bellies							
1970–77	3.656 (1.230)	8.994 (5.236)	250 (2.2)	3.4	8.2	3.0	0.0
90-Day Treasury Bills							
1978	2.021 (0.320)	3.374 (1.109)	n.a.	12.2	13.1	9.9	0.0
GNMA Mortgages							
1978	1.125 (0.034)	1.494 (0.179)	n.a.	30.9	33.4	29.9	11.0

Note: Based on data from Commodity Futures Trading Commission, "Commitments of Traders," monthly (formerly available in USDA "Annual Summary of Commodity Futures Statistics").

[a] The periods for wheat, corn, soybeans, and Maine potatoes are crop years and the indicated year is the year of the harvest. All wheat is the sum of positions in Chicago, Kansas City, and Minneapolis.

[b] Working's speculative index $= 1 + \frac{SS}{HS + HL}$, when $HS \geq HL$,

$$= 1 + \frac{SL}{HS + HL}, \text{ when } HL > HS,$$

where HS and HL are total short and long hedging and SS and SL are total short and long speculation. All unmatched reported spreading was assigned as speculation. The difference between the lower and upper bound estimates is described in the text. Standard deviations appear in parentheses.

[c] See text for a discussion of the limits reported here. Figures in parentheses are limits as a percentage of the average open interest.

sults; the allocation model used here showed a positive relationship between the percentage of nonreporting positions which are hedging and the percentage of open interest which is reported hedging. When applied to current data from the major agricultural markets and their large hedging percentages, this procedure allocated the majority of the nonreporting positions to hedging. Hence, hedging is probably overstated and the speculative index calculated from these allocations generally provides lower bound estimates of the speculative character of the market. Both upper and lower

allocation model was reestimated with logs of ratios of the percentage distributions as dependent variables and the same set of independent variables. The estimated percentages are thus constrained to the (0, 1) interval.

bound estimates of the speculative index are reported in table 1.

The examined markets include wheat, corn, soybeans, pork bellies, live cattle, Maine potatoes, 90-day treasury bills, and GNMA mortgages. The commodities encompass a variety of production and marketing attributes, including storable grains, nonstorable and continuously produced products, and government-secured debts. These markets also reflect a range of speculative and hedging participation as reflected in the estimates of the speculative index and the average percentages of the open interest which are reported long and short hedging. Also included in table 1 are measures of offset hedging and balanced hedging, based on the reported hedging data only. "Offset hedging" is simply the smaller of short or long hedging, which defines the maximum amount of hedging which could be offset by other hedging. It measures the amount of hedging in a market which is mathematically balanced, ignoring the kinds of differences in long and short hedging requirements noted above. "Balanced hedging," on the other hand, takes account of the likelihood that hedging would be offsetting, given the speculative character of the market and the total amounts of long and short hedging. It is derived from Working's index. Balanced and offset hedging are calculated only for the case when all small positions are assumed to be speculative to enable direct comparisons between reported positions and the two measures of hedging balance.

The upper bound estimates of the speculative index range from 9.0 for pork bellies to 1.2 for corn and wheat in the 1972–77 period, while the lower bound estimates range from only 3.7 to 1.0. As T cannot be less than one—there must be enough speculation to offset the unbalanced hedging positions—these averages are remarkably low. Interestingly, if the results for the pork belly market are ignored, then the two financial markets represent both ends of the speculative spectrum and are not dissimilar from the agricultural markets. Under both the upper and lower bound estimates, the treasury bill futures market appears to be twice as speculative as the GNMA market. This difference is mostly illusory and reflects the difficulties of intercommodity comparisons based on the reported positions data and of the accepted procedures for apportioning small positions as hedging and speculation. Reporting requirements in the two markets are identical at twenty-five contracts. Thus, a position in treasury bill futures representing $25 million is reportable, while one of only $2.5 is reportable in GNMAs. Data from the first full market survey showed total hedging of similar proportions on both markets (Hobson). A more recent survey shows total hedging in treasury bills to have been nearly twice that on the GNMA market, a reversal of the average reported hedging results (Jaffe and Hobson). Using the allocation procedure does not alter the basic result since small trader hedging is positively correlated with reported hedging and no adjustment is made in the procedure for differences among commodities as to reporting requirements.[2]

Though the sample is quite small for these two markets (twelve observations), the results were retained to provide comparisons with the agricultural markets and to highlight the need for more careful attention to the question of reporting requirements and its effects on the description of a market provided by the positions data. Research is needed to create a better allocation scheme, one which would correct for deficiencies in the data and not exacerbate them.

Among the agricultural commodities, two distinct groups of commodities emerge, using either the upper or lower bound estimates. The wheat, corn, and soybean markets are characterized by very low relative levels of speculation. Maine potatoes, live cattle, and pork belly markets have considerably more speculation, with the belly market nearly twice as speculative as the other two. The dichotomy is especially strong if the 1972–77 indices for three major markets are used in the comparison. Speculation in contemporary wheat, corn, and soybean markets is barely adequate, while that in the cattle, pork belly, and potato markets is somewhat greater.

Coincidentally, these groups of commodities are dichotomous in the levels of speculative limits which have been established. Corn, wheat, and soybean limits, set by the CFTC, are currently at 3 million bushels. While the limits in the corn and soybean markets have been at 3 million bushels since 1971 (the entire 1972–77 period), that in wheat was increased

[2] Both Rutledge and Larson included shifter variables in their equations for the different commodities included in the full market surveys, but these were not significant and were excluded in the final estimates. Also, the financial market surveys were not included in either Rutledge's or Larson's work and were hence excluded in the estimates used here.

to 3 million only in August 1976. For the bulk of the 1972–77 period, a limit of 2 million bushels applied, and this is shown as the limit in column 3 of table 1. The limits for all these commodities averaged less than 1% of the open interest, irrespective of which limit is used for the wheat market. Limits on speculative positions in potatoes were established by the CEA in 1964, those for cattle and pork bellies are set by an exchange, and speculative positions in cattle are limited by maturity but not as an overall position. These limits are significantly greater percentages of open interest than in the three major markets, averaging more than 2% of their respective open interests.

These data call into question the adequacy of Commission review and evaluation procedures for the establishment of limits. Further, they suggest some intriguing possibilities for intercommodity, market performance research. Are there measurable differences in price behavior between markets with minimal speculation and those with larger amounts? Would these comparisons lead to an estimate of a desired level or even an adequate level of speculation? Speculation in the wheat market with an index of 1.04 (1.18 upper bound) may be inadequate and pork bellies at 3.66 (9.0 upper bound) may be more than adequate from the point of view of optimal market performance. The contrast between pork bellies and potatoes is also intriguing. The limits generally are more restrictive in bellies than in potatoes, yet the speculative index for bellies is larger, suggesting that more than the absolute size of the open interest needs to be considered in establishing limits.

The need for market performance research is emphasized by the significant historical changes within the corn, wheat, and soybean markets. In the decades of the 1950s and 1960s, these markets would hardly have been characterized as speculative. The soybean market, with the least amount of continuous government control, was the most active market and the speculative index was greatest. For all three markets, the speculative index has significantly decreased in the post-1972 period, the period in which these markets have been characterized as being speculative. In reality, speculation was barely adequate on average. A related fact, documented by Gray (1979), is that, far from causing the explosive price increases of 1973–74, speculation, which was net short over the period of the price rise, obviously helped to contain it. The general inadequacy of speculation on these markets is further suggested by the extreme daily price moves; soybean futures prices, for example, frequently touched upper and lower limits on the same day. These and other market performance issues need to be considered in conjunction with the obvious constraints on speculation in the three markets. Such research might lead to speculative limits more responsive to the needs of markets.

Speculation on the Three Wheat Markets

The speculative indices for wheat, reported in table 1, were based on aggregate positions in all three wheat markets, Kansas City, Chicago, and Minneapolis. Minneapolis and especially Kansas City are preferred hedging markets for the hard wheats. They specify delivery of spring and hard winter wheats, respectively, in locations desirable for many hedging purposes. In the 1972–77 period reported long hedging averaged 87% of the open interest and short hedging averaged 86% in Kansas City. The comparable percentages in Minneapolis were 82% and 81%. Hedging in the Chicago market, on the other hand, averaged only 45% of the long open interest and 52% on the short side. The average month-end open interests were 194.7, 87.6, and 27.1 million bushels on the Chicago, Kansas City, and Minneapolis markets, respectively. Thus, while more important in the composition of the Kansas City and Minneapolis markets, aggregate hedging positions are largest in Chicago.

Estimates of the speculative index and the extent to which hedging may be viewed as offsetting or balancing are reported in table 2 for the separate markets. In the pre-1972 period, Chicago was the most speculative of the three markets. In this period, the indices show there was some speculation at the Kansas City and Minneapolis markets above that minimally required to offset hedges. Previous research documented that a significant portion of speculation at Kansas City and Minneapolis was from traders who were willing to assume positions in those markets only when they simultaneously assumed offsetting positions in Chicago. Gray (1967) showed that the net positions of the reported spread traders showed a close correspondence to the net positions of the reported hedgers at both Kansas City and

Table 2. Measures of the Speculative Index (*T*) and Hedging Balance on the Three Wheat Futures Markets

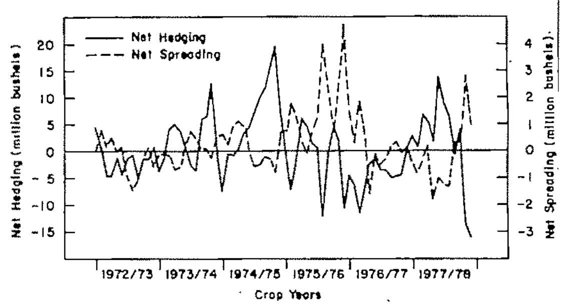
	Lower Bound Estimates			Upper Bound Estimates		
Market/ Period	*T*	Offset Hedging	Balanced Hedging	*T*	Offset Hedging	Balanced Hedging
		(%) of open interest			(%) of open interest	
Chicago wheat						
1947–71	1.355 (0.261)	13.6	2.6	1.891 (0.536)	19.3	10.6
1972–77	1.094 (0.053)	41.4	22.0	1.323 (0.123)	50.6	42.2
Kansas City						
1947–71	1.081 (0.086)	43.8	29.3	1.264 (0.221)	56.2	49.6
1972–77	1.009 (0.008)	83.1	76.2	1.045 (0.026)	88.1	86.1
Minneapolis						
1947–71	1.056 (0.075)	50.7	36.3	1.230 (0.192)	64.7	60.0
1972–77	1.013 (0.010)	75.1	65.9	1.070 (0.047)	85.7	83.5

Note: Based on the monthly reported positions data from the Commodity Futures Trading Commission (formerly Commodity Exchange Authority). Years are crop years. Standard deviations of *T* appear in parentheses. See text for a description of the upper and lower bound estimates.

Minneapolis. This unbalanced spreading was in fact speculation from Chicago. The subsidiary markets survived only because necessary speculation could be transfused from another market.

In the post-1972 period, the speculative indices on all three markets have decreased significantly, in spite of tremendous growth in each of the markets. The indices for Kansas City and Minneapolis are negligibly greater than minimal values. Significantly, the index at Chicago also has decreased to a value close to that of the two subsidiary markets in the earlier period. The Kansas City market is of particular interest in these comparisons, and the relationship between hedging and net spreading at Kansas City in the post-1972 period is shown in figure 1. As with Gray's results, there is clearly a close inverse relationship with net spreading and net hedging. The significant difference from his earlier results is the magnitude of the response of spreaders to changes in net hedging. In the earlier period, the unbalanced spread positions were of the same order of magnitude as net hedging positions. More recently, changes in the net spread positions are approximately one-fifth those of the net hedge positions. The explanation of this change is most likely tripartite. First, Kansas City may have grown enough in the recent period to attract nearly sufficient speculation, thereby becoming less reliant upon Chicago for its needs. Second, the significant decline in speculation relative to hedging needs in Chicago suggests there is little remaining "excess" speculation in Chicago to respond to the needs of the subsidiary market. Third, the aforementioned closer balance between short and long hedging provides more offsetting hedging. Kansas City continues to suffer from a lack of speculation, though the deficit is smaller now than in the past. In fact, all three wheat markets appear to have inadequate speculation.

In light of these results, a recent statement (Stone, p. 56) by the current chairman of the CFTC, who said, "Relatively few markets fit



Note: Based on data from CFTC, "Commitments of Traders," monthly.

Figure 1. Hedging—spreading relationship in Kansas City wheat futures, monthly 1972–77

the textbook description of a futures market: one in which most of the business is commercially oriented, with just enough speculation to provide the lubrication the system needs. One that does, for example, is the Kansas City wheat market . . ." can only be termed astonishing. Speculation at Kansas City is manifestly inadequate—an inadequacy which is apparent every day is spreading to Chicago. And while the spreading manifests the inadequacy, it does not measure it—its true measure would require knowing how much more price sacrifice would be entailed in placing a trade at Kansas City absent the Chicago spread opportunity, in addition to the price sacrifice already encountered in the presence of the spread opportunity. If Chairman Stone finds so inadequate a market as that for Kansas City wheat to be so nearly ideal, why does he not exhume the markets for bran and shorts, which died there for lack of speculation?

Conclusion

The role of speculation in commodity futures markets is perhaps the least well understood economic activity. Its existence has been the source of much regulation, its abuses serve only to focus attention on our ignorance. The data assembled here attempt merely to refocus attention, providing a view of the speculative composition of a variety of markets. These data confirm the inadequacy of speculation on the tributary wheat markets and suggest its inadequacy in wheat, corn, and soybeans generally. Coincidentally, speculation was most inadequate on those markets with the most restrictive position limits.

The diversity in speculative composition among markets suggests a variety of interesting, useful research needs. Are there detectable differences in price behavior among markets with significantly different speculative components or within markets where relative speculation has changed significantly over time? Is price behavior measurably different in the Kansas City wheat market, with its still inadequate speculation, than in Chicago? Has this difference changed over time? In markets characterized by barely adequate speculation and hence low speculative indices, much hedging is required to be balancing, more than might be expected on a well-functioning, liquid market. Are the costs of hedging higher on these markets? Have higher costs altered significantly hedger's use of the markets?

Analysis of these market performance issues has not been attempted. Rather, the analysis documents pronounced differences in speculative adequacy among a variety of futures markets. That market performance research is needed is clear. Economic analysis which focused upon these questions could contribute both to our inadequate knowledge and, hopefully, to enlightened regulation.

References

Commodity Futures Trading Commission. *Commitments of Traders*, monthly, 1974–79.

Cowing, Cedric B. *Populists, Plungers, and Progressives*. Princeton, N.J.: Princeton University Press, 1965.

Gray, Roger W. "Characteristic Bias in Some Thin Futures Markets." *Food Research Institute Stud.* 1(1960):296–312.

———. "Price Effects of a Lack of Speculation." *Food Res. Inst. Stud.* 7(1967, Supplement):177–94.

———. "The Emergence of Short Speculation." *Int. Futures Trading Seminar, Proceedings VI*. Chicago: Chicago Board of Trade, 1979.

Hobson, Ronald B. *Futures Trading in Financial Instruments*. Washington, D.C.: Commodity Futures Trading Commission, Oct. 1978.

Jaffe, Naomi L., and Ronald B. Hobson. *Survey of Interest-Rate Futures Markets*. Washington, D.C.: Commodity Futures Trading Commission, Dec. 1979.

Larson, Arnold B. "Estimation of Hedging and Speculative Positions in Futures Markets." *Food Res. Inst. Stud.* 2(1961):203–12.

Peck, Anne E. "The Influence of Hedging on Futures Markets Activity: Some Further Evidence." *Int. Futures Trading Seminar, Proceedings VII*. Chicago: Chicago Board of Trade, 1980.

Rainbolt, John V., II. "Regulating the Grain Gambler and His Successors." *Hofstra Law Rev.* 6(1977):1–25.

Rutledge, David J. S. "Estimation of Hedging and Speculative Positions: An Alternative Approach." *Food Res. Inst. Stud.* 16(1977–78):205–12.

Stone, James M. "Commodities Markets: Why So Volatile?" *U.S. News and World Report*, 30 June 1980, pp. 56–7.

U.S. Department of Agriculture, CEA. *Annual Summary of Commodity Futures Statistics*. Washington, D.C.: Statist. Bull. 1947/48–1971/72, annually, and *Commitments of Traders*, 1972–74, monthly.

Working, Holbrook. "Speculation on Hedging Markets." *Food Res. Inst. Stud.* 1(1960):185–220.

Inventive Activity in Futures Markets: A Case Study of the Development of the First Interest Rate Futures Market

Richard L. Sandor and Howard Sosin

The GNMA Futures contract that began trading in 1975, and the one that trades today, retains much of the character of an agricultural commodity futures contract. That is, it carefully balances the diverse interests of cash and futures market participants and the diverse interests of potential longs and shorts. Alternatively stated, the key considerations in designing this contract were a desire to obtain active participation of floor traders along with the desire to encourage use by the trade. Participation by these parties ensures liquidity, helps to provide an inexpensive hedging vehicle, and guarantees convergence between cash and futures prices.

This paper traces the development of the GNMA Futures contract from first draft to final product. The evolution of the provisions of the contract is of interest as it provides insights into the art of contract design and because it provides information that may be useful in evaluating the potential of the more than forty-five proposals for futures contracts that are currently pending at the Commodity Futures Trading Commission. The provisions of the contract that are analyzed include contract size, tick size, daily limit, position limit, and deliverable trade.

In addition to carefully balancing the interests of potential participants, the GNMA contract was designed to reflect the regulatory environment of the time. This paper discusses the role of the Commodity Exchange Authority, the Federal Home Loan Bank Board, the Securities and Exchange Commission, and the Commodity Futures Trading Commission. It describes a draft of a bill that would have given the Federal Home Loan Bank regulatory authority over mortgage futures; the 1974 effort by exchanges, regulators, and individuals to define the word "commodity" to ensure an unambiguous regulatory environment; the approval of the GNMA contract by the CFTC; the effort by the SEC to block trading; and the recent court case concerning the establishment of trading months.

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Editor's Note: The authors submitted the above abstract in lieu of a paper.

Futures Markets: The Interaction of Economic Analyses and Regulation: Discussion

Gary L. Seevers

Regulatory problems which require a heavy input of economic analysis can be placed in three categories.[1]

The first is the age-old issue of speculation. What are its economic functions? What are the consequences of various amounts and types of speculative activity? Should speculation be regulated and, if so, how? The Peck paper deals with some question in this category.

The second category covers the growth of futures trading, particularly into new commodity areas. Currently, there are numerous regulatory questions that stem from the expansion of trading into "macroeconomic" commodities such as the successful new GNMA contracts discussed in the Sandor-Sosin paper. Specifically, regulators are concerned about the effects of the rapid spread of futures trading in financial futures and the proliferation of essentially identical contracts at different exchanges.

The third category includes various regulatory restrictions on market access and flexibility, such as daily price limits, setting "closing" prices, position limits, as well as controls on foreign traders and computerized trading programs. Neither paper really addresses these more technical issues.

I agree with Peck's concluding statement that "The role of speculation in commodity futures markets is perhaps the least well understood economic activity. Its existence has been the source of much regulation, its abuses serve only to focus attention on our ignorance." As she acknowledges, the paper does not add very much to alleviate our ignorance.

I have three specific comments on the Peck paper. First, using the Working index, she shows that hedging has become more important compared with speculation in the grains complex since the early 1970s. The need to hedge the expanded marketings of grains clearly has been the primary reason for greater activity in grain futures; it is significant that hedging has increased in a relative sense.

Second, the paper distinguishes between markets like pork bellies that have a continuous high level of speculative activity and speculative problems of a temporary character, such as those that have occurred in particular delivery months. Much more could be done to examine various types of speculative activity. Certainly trading activity by the professional "local" trader should be separated from that of the part-time "retail" investor and also from the large investor who may be accumulating sizable positions for long-term investment purposes.

Third, her empirical findings show that speculation is considerably more significant for some commodities than for others. She attributes the low speculation in grains to government-set position limits which have existed since the 1930s. While I agree that limits are low, there is another explanation that she should explore. The commodities with low speculative indexes are commodities that always have a physical inventory to be carried forward. Grains, soybeans, and GNMAs are inventory commodities and for these the prices in deferred delivery months are consistently related to current inventories. In contrast, commodities like livestock products and treasury bills have higher speculative indexes. For these commodities, inventories play a small or minor role, and pricing of deferred months depends mainly on anticipated production and demand rather than on current supplies. Futures markets in noninventory

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[1] Excluded here are problems that involve the protection of individual investors and users of futures, as well as various types of trading irregularities that do not affect general market performance.

commodities may require more speculation to function, or they may just attract more speculation.

The Sandor-Sosin paper makes the point that those who were involved in designing the GNMA futures contract made good use of their knowledge about agricultural futures. Since the GNMA contract has been successful and has pioneered a new area of futures trading, this is an important by-product of our years of experience with agricultural futures.

However, this paper should have been a case study about how regulation can either deter or expedite an innovative concept. The idea of a futures market in mortgages originated, no doubt, in many places. It was advanced in 1971 when the concept was presented to the Securities and Exchange Commission (SEC), an agency often regarded as the premiere federal regulatory agency. However, the SEC reacted in a negative way and the supporters of the idea considered the prospects for SEC approval to be bleak.

A couple of years later Congress created another independent agency, the Commodity Futures Trading Commision (CFTC), to regulate futures trading and also broadened the scope and extent of regulation. In the process, the legislative history made clear that Congress wanted the CFTC to have exclusive regulatory jurisdiction over all forms of futures trading. Two months after CFTC started its work, in April 1975, the Chicago Board of Trade submitted a GNMA contract for approval; trading began only a few months later in October 1975. Subsequently, various exchanges submitted other interest-rate futures contracts, which eventually were approved by CFTC. Today a brand-new area of futures trading exists that might not exist without a major change in the regulatory structure.

As those who follow futures regulation know, this is not the end of the story. The jurisdictional dispute continues and has been intensified by problems in silver trading that erupted earlier this year. The jurisdictional dispute probably will require further congressional action in order to resolve and clarify the roles of various agencies including the CFTC, the SEC, the Federal Reserve Board, the U.S. Treasury Department, and possibly other agencies such as the Department of Agriculture.

I would say that what Congress helped create could be damaged or even destroyed if Congress were to splinter jurisdiction for the regulation of futures trading among several agencies. And, if this is done for interest-rate futures, it is quite conceivable that agricultural futures could be similarly affected at some point. Quite clearly, the regulation of futures is an unsettled area. The way it is resolved will certainly affect the rate of innovation in futures markets, which is the main point in the Sandor-Sosin paper.

These two papers, seemingly unrelated to each other, deal with aspects of the same general skepticism and misunderstanding that has plagued futures trading for decades. Due to lack of understanding particularly about speculation, as well as periodic abuses and market problems, there is a propensity to add more government regulation. Likewise, lack of understanding of the economic role of futures has kept government agencies from permitting new concepts to proceed. It seems clear that this state of affairs will continue in the foreseeable future.

Futures Markets: The Interaction of Economic Analyses and Regulation: Discussion

Reynold P. Dahl

We commend our speakers for interesting and thought-provoking papers. However, neither focuses clearly on the theme of this session. Peck comes the closest with an analysis of market composition between hedging and speculation. But, this dichotomy has proven to be of limited value in futures market regulation. I fear it also has limited value as a research tool. Sandor and Sosin present a useful historical review of the evolution of the GNMA futures contract, but its regulatory implications are unclear. Futures market regulation continues to be a ballgame in which lawyers are carrying the ball, with economists on the sidelines.

Public criticism of futures markets over the years, as Peck points out, has been heavily concentrated on speculation. Futures markets facilitate speculation and speculation is considered objectionable for two main reasons. First, to many people, speculation is synonymous with price distortion or manipulation. Second, speculation is said to contribute to frequent and unwarranted variability in futures prices as well as in spot prices. These criticisms are long-standing and reflected in the futures market regulatory legislation which mandates the close monitoring and control of speculation through a reporting system and speculative position limits.

Experience has shown, however, that fixed speculative position limits are ineffective regulatory tools. Speculators are not a greater threat to efficient market performance than hedgers whose normal operations often involve large positions in both cash and futures. Efficient futures markets require both hedgers and speculators. The economic distinction between them is more illusory than real.

The real problem, in my view, is that economists have not done a very good job in helping the general public distinguish between speculation and manipulation. The two terms are not synonymous. It is price distortion or manipulation, regardless of its source, that demands more study rather than speculation, per se. What is price distortion or manipulation? How can it be detected? Is it a problem in maturing futures in certain delivery months? What constitutes "orderly markets" and "orderly trading" in the delivery month? Unless reasonable answers to such questions are obtained, I fear we are headed for more rigid government controls on futures trading, which could have deleterious effects on market performance. Proposals to increase margin requirements and place them under government control are examples.

Increased speculative position limits also have been proposed despite their proven ineffectiveness in preventing market abuse. The Commodity Futures Trading Commission (CFTC) has recognized the inefficiency of fixed speculative position limits. The agency has been searching for alternative regulatory tools that would assist it in monitoring possible price distortions that may occur in the delivery month of certain maturing futures due to technical conditions or squeezes. Hence, it proposed the so-called "Twenty-five Percent Rule" on 13 April 1978. This proposed rule provided that no contract market would permit any trader (speculator or hedger) to have a position in excess of 25% of the open interest during the last fifteen days of the delivery month unless the market determined that the holding of such a position is not likely to result in price manipulation or market congestion (Federal Register, p. 15440). This proposal received a cool reception from the markets, who considered it unworkable for a host of reasons.

The CFTC could well have undertaken economic analysis on the possible feasibility and

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efficacy of such a rule before proposing it. The agency has an important regulatory role to play in the detection and prevention of possible distortions in futures prices. It needs more guidance from economists as to the nature of the problem, if it exists, and how best to deal with it. Heifner also has proposed prescribed limits on traders' positions during the last few weeks of trading in a maturing future. While his proposed limits are similar in intent to the proposed CFTC "Twenty-five Percent Rule," they would be a function of the deliverable supplies rather than the open interest. Such proposals merit more study in the search for workable alternatives to speculative position limits as regulatory tools.

The rules and regulations of all contract markets provide for self-regulation through business conduct committees composed of members assisted by professional staff that are charged with the responsibility of preventing price manipulation. The CFTC also has this responsibility as directed by Congress through legislation. Heifner has articulated what he views as a serious problem in sharing regulatory responsibility between the CFTC and the markets. This stems from different philosophies of regulation as to what constitutes price distortion. Cases have arisen in the past where the CFTC saw a threat of price distortion in a maturing future while the markets found no such evidence and, consequently, no need for emergency action. Similar cases are likely to arise in the future. I agree with his assessment that it is extremely important to establish equitable procedures for dealing with such situations. Again, this calls for better economic information as to what constitutes "price distortion," "orderly markets," and "orderly trading."

Futures contract terms also impinge on market performance and merit continuous economic analysis. In fact, proper contract terms may be more effective in preventing market abuse than any regulatory action after the abuse has occurred. It is in their own best interests for the markets to review continuously the terms of their contracts and alter them when needed to meet changing economic conditions and marketing patterns.

In concluding, I will make several general observations on futures market regulation from the perspective of someone who has served as a public director of a contract market for the past eight years. Congress created the CFTC in 1974 when prices were extremely volatile. To its credit, Congress considered and rejected many specific regulatory restrictions that would have had adverse effects on market performance. But, it did give broad discretionary authority to the new Commission. The implementation of the legislation to date has been disappointing to many. Of course, it takes time to develop effective regulatory policies and procedures. But, an important reason for many confrontations and open conflicts that have developed between the markets and the new Commission is that it has moved forward simultaneously on many perceived regulatory problems without clearly defined priorities. Economic analysis has played only a limited role in defining regulatory priorities.

An efficient system of futures market regulation is in the best interest of both the markets and the general public. More economic analysis is needed to help define regulatory problems and policies. Better working relationships between the markets and the CFTC also are needed for the delineation of the appropriate roles for self-regulation and government regulation of futures markets.

References

Federal Register, vol. 43, no. 72, 13 Apr. 1978, pp. 15438–41.

Heifner, Richard G. *Report on a Study of the March 1979, Chicago Wheat Futures Contract*. Study commissioned by the Subcommittee on Conservation and Credit, House of Representatives Committee on Agriculture, hearings held 28 Mar. 1979.

Inflation Effects on Financial Performance and Structure of the Farm Sector

David A. Lins and Marvin Duncan

Inflation is measured as the rate of increase in the general price level. As Samuelson and others point out, the problem with inflation is not so much price increases, but rather the inefficiencies and inequities that result from inflation-induced changes in relative prices. Relative price changes affect supply-demand relationships for both factor and product markets. Changes in these relationships in turn influence the level and distribution of income, asset values, cash flows, debt, net worth, and structural characteristics of farm firms. The objective of this paper is to provide a broad overview of inflation's impact on the financial performance and structure of the farm sector.

Relative Price Changes during Inflation

Correlations between the inflation rate (measured as the percentage change in the Consumer Price Index) and the percentage change in various prices paid and received by farmers give some indication of the relative price changes that can occur during a period of general price inflation. Obviously, factors other than inflation also affect relative prices. Changes in supply-demand relationships probably have the major impact. However, correlations calculated over the 1949–79 period by subperiods and by whether the inflation rate was above or below trend are revealing. Table 1 displays some of the more important correlations.

The percentage change in prices paid on production items is more highly correlated with the rate of inflation than is the percentage change in prices received. The disparity between these correlations has grown in more recent years. Moreover, this suggests that in the short run, a higher inflation rate may be associated with higher prices paid on production items without a corresponding adjustment in prices received. If so, this can lead to greater variability in farm income.

Substantial differences among correlations are evident. For example, during the 1965–79 period, changes in prices received on crops were more highly correlated with inflation than prices received on livestock and livestock products, a reversal from the 1949–64 period. Correlations between the percentage changes in prices received and paid and the inflation rate from the period 1965–79 tend to be lower than for the 1949–64 period. This undoubtedly reflects greater price variability in more recent years. Recent government programs that link price supports and target prices to costs of production may, however, tend to make commodity prices more responsive to inflation affecting costs of production.

An important component in the cost of production is interest expenses. The relationship between nominal interest rates and the inflation rate has an important bearing on financial performance and structure of the agricultural economy. While past evidence shows that interest rates paid by farmers did not move in tandem with national financial market rates, that circumstance is changing. As farm credit markets are more closely linked to national financial markets, interest rates to farm borrowers likely will track financial market rates more closely and exhibit greater variability than has previously existed.

Effects of Inflation on Financial Performance

Inflation has differing long-run and short-run impacts on the financial performance of the farm sector. In the short run, inflation may

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contribute to reduced farm income, increased capital gains, reduced liquidity, and greater income instability. In the long run, financial outcomes may not be substantially altered, but firms in the industry may adjust toward those who can best deal with income instability and capture growth opportunities.

While empirical quantification is beyond the scope of this paper, we hypothesize that inflation (*a*) increases the income variability associated with agricultural production activities; (*b*) affects farm income more in the short run than in the long run; (*c*) affects the nominal and real value of assets, especially farm real estate; (*d*) increases the reliance on debt financing; and (*e*) creates cash flow stress for farm firms.

Income Variability

As shown in table 1, farm production costs have been more closely linked with general inflation rates than have prices received by farmers. This circumstance reflects differences in structure between the farm input and farm production sectors of the economy. Input suppliers often operate within a framework of administered prices. Hence, higher inflation translates into higher farm production costs without a necessarily corresponding short-run response in farm prices received. Income variability for the farm firm is thus increased.

Not all segments of farm production are affected equally by inflation. For example, dairy prices, administered through a complex set of milk-marketing orders, respond quickly to inflation. Increased export demand for food grains, oil, seed crops, and cotton has caused the percentage increase in these commodity prices over the past decade to exceed that of the index of prices paid by farmers. In contrast, the prices of meat animals, feed grains, and fruit have not increased as rapidly as production costs. Rising energy costs have affected the income, wealth, and liquidity positions of heavy energy-using farming operations, especially irrigated agriculture. Consequently, inflation has been associated with intrasector variability in the incomes of producers. The use of public policy to dampen this variability has, thus far, met with mixed success. In fact, Schultz argues that adding artificial stability to one segment of the agricultural sector adds instability to other segments of the sector.

Inflation also leads to greater variability in farm income because farm input firms can pass price risks on to farmers. A recent example is in financial markets where a marked shift by lenders toward variable interest rates—either explicitly or *de facto*—has occurred. This, coupled with changes in implementing monetary policies, means that farm borrowers face increased interest rate variability. This increases farmers' financial risks and may cause changes in farm financial structure in response to higher risk.

Level of Income

Because price inflation can result from increases in only a few components of the consumer price index, it is difficult to generalize the impact of inflation on the level of farm income. For example, CPI increases that result from price increases for raw agricultural products could result in improved farm incomes. In contrast, inflation resulting from increased prices of farm inputs could adversely affect farm income.

Tweeten and Quance, however, have shown that there is not a one-to-one correspondence between input price increases and reduced farm revenue. The supply-induced response to higher prices has a tendency to dampen the adverse effects of input price increases. In

Table 1. Correlations between Changes in the Consumer Price Index and Changes in Selected Prices Paid and Received by Farmers

	Percentage Change in Consumer Price Index				
Percentage Change in Index of	1949–79	1949–64	1965–79	Inflation above Trend[a]	Inflation below Trend[a]
Prices paid on production items	.82	.80	.71	.77	.67
Prices received	.48	.77	.19	.32	.36
All crops	.42	.63	.29	.37	.16
Livestock and livestock products	.45	.78	.00	.24	.42

[a] A linear trend line was fit to determine those years in which the inflation rate was above or below trend.

evaluating increases in input prices, Eleveld found that nominal net farm income increased, but real net farm income decreased due to the concurrent rise in the consumer price index. In contrast, Tweeten and Griffin estimated that each percentage point increase in the inflation rate reduces net farm income by $.7 to $2 billion in nominal dollars. On balance, inflation in input prices can reduce net farm income in the short run. But, significantly, inflation in product prices can increase net farm income.

The long-run impact of inflation on farm income is not clear. Ruttan argues that inflation dampens productivity growth. This seems intuitively reasonable, since inflation tends to discourage research and investment with long payback periods—the kind often associated with productivity increases. Milton Friedman suggests that inflation also leads to economic inefficiency because it makes prices a less efficient system in coordinating economic activity. However, we know of no evidence to suggest that the long-run impacts of inflation are any more severe for agriculture than for other sectors of the economy.

Value of Assets

Nominal and real capital gains on farmland have been substantial over the last two decades. Lins has shown that over the 1960–79 period, nominal gains on farmland averaged 9.3% annually, while real gains averaged 4.2%. Over the same period income returns to land grew at an annual rate of 14.8% in nominal terms and 9.7% in real terms, thus exceeding the capital gains rate on land. The implications of these relationships have not been completely reflected by the popular press.

It is commonly agreed that price inflation leads to higher nominal prices for farmland. But does price inflation lead to an increase in the real price of farmland? Reviewing past growth in real prices of farmland during periods of relatively high inflation has led some analysts to answer yes. We contend that the conclusion is misdirected.

Melichar has shown that the growth in the real value of farm real estate is explained by the growth in real income returns to land. It is this growth in real income returns to land that has sparked the growth in real land values. If inflation has an adverse effect on real net cash flows, then inflation likely would lower the real value of farm real estate. The fact that real values of farm real estate increased in the face of substantial inflation does not refute this argument, unless one argues that policy makers either purposely or because of misinformation enacted farm policies which interacted with inflation in the economy to raise real returns to land. This latter explanation seems plausible.

Reliance on Debt Financing

Farm firms have relied increasingly on debt financing to finance the operating inputs and capital assets used in farm production. For example, from 1950 to 1978 the number of farm real estate transfers on which debt was incurred increased from 58% to 89%. Over the same time, debt as a percentage of purchase price increased from 57% to 76% on those debt-financed purchases. Likewise, the proportion of total capital purchases financed with debt capital increased from 17% in 1950 to 50% in 1978 (USDA 1979a).

Because many factors are involved, explicit determination of the impacts of inflation on debt financing is difficult. However, it does appear that inflation has contributed to increased reliance on borrowed funds. Past inflation has contributed to the expectations of continued inflation. In an attempt to obtain the benefits of capital gains, investors are encouraged to "buy now" before the price goes even higher. Lacking the reserves to pay cash, the investor borrows the money. Since total returns (income plus unrealized capital gains) from farm real estate investment have exceeded the cost of borrowing, debt financing of farmland has increased the investor's equity growth.

Cash Flow Stress

There is considerable evidence that the liquidity position of farm firms has decreased over time. For example, Lins has shown that the percentage of liquid assets of farm firms (financial assets and crop and livestock inventories) has decreased relative to fixed assets such as farm real estate and machinery. This may be in response to inflation's impact on relative rates of return to assets held by farmers. Likewise, the ratio of debt outstanding to net cash income has trended upward over time, implying a higher proportion of net farm income must be allocated to debt service. Thus, farmers are increasingly exposed to cash flow stress.

The cash flow stress fueled by inflation is perhaps most readily apparent in the acquisition of farm land. As expected inflation in land values and the net returns to land increase, the price paid for land becomes more a function of expected inflation rather than current returns. Investors who finance the purchase of land with borrowed funds find that the cash returns from the land in the early years are not sufficient to make the loan payments. These deficiencies must be made up from other sources such as financial reserves, nonfarm income, or income from other land. If expectations of inflation increase, this early-year cash flow deficiency in meeting loan payments likely will rise. Conversely, were inflation rates to decline—and rates of increase in returns attributable to land as well—the early-year cash deficiencies could be even more extended.

Effects of Inflation on Structure

Recently, considerable effort has been devoted to studying the structure of U.S. agriculture and the role of public policy in shaping such structure. Three major publications: *Another Revolution in U.S. Farming?*, *Structure Issues of American Agriculture*, and *Farm Structure* have resulted from these efforts. While each publication contains papers which allude to impacts of inflation on U.S. agriculture, researchers have been cautious about ascribing any cause-and-effect relationship. Because empirical testing is difficult, the following should be considered a set of tentative hypotheses about the impacts of inflation on selected elements of the structure of agriculture. We hypothesize that inflation (*a*) leads to fewer and larger farm firms; (*b*) encourages ownership of assets, but makes them more difficult to obtain; (*c*) encourages (with the aid of existing regulations) a move toward a corporate form of business organization; and (*d*) encourages vertical integration and coordination.

Fewer and Larger Farms

Inflation has encouraged the trend toward fewer and larger farms. This is most obvious in the case of farm real estate. Encouraged by past inflation, existing landholders have used their wealth to buy additional land. The purchase of land is most easily accomplished by well-established operators or people with substantial sources of off-farm income.

Both the variability in farm income and the rewards for risk bearing—in the form of higher leverage ratios—are increased by unexpected inflation. Since not all farm sector participants are willing or able to bear such risk, those less averse to risk—and able to bear it—tend to accumulate additional assets. Inflation interacts with numerous other factors in encouraging these kinds of structural change, as well.

Ownership of Assets

The ownership of farm sector assets, especially land, has been desirable because of the favorable growth in real values. Both farm and nonfarm investors have come to view land as a good hedge against inflation. However, present owners tend to retain their land for the same reason. The restricted supply coupled with strong demand has exerted strong upward pressure on land values.

The upward pressure on land values has created a selectivity in who can purchase land. Income returns to current market value of land have averaged about 5% in recent years, while unrealized capital gains have added around 12% annually to land values. The combined average return of around 17% has been favorable relative to the cost of borrowed funds and relative to other investment options. But if a significant portion of the sale price is borrowed with interest rates at 8%–12%, the land being purchased will not generate a sufficient cash flow to make the loan payments. Only those with access to funds generated outside the land being purchased can meet the cash flow requirements. Hence, concentration of land ownership among existing landowners is a logical and economically rational consequence.

Business Organization

Reimund has shown that both the number of farms and the amount of land in farms controlled by firms organized as corporations have increased over time. The move to a corporate form of business organization reflects in part the interaction of inflation with public policies such as federal income and estate taxes.

Inflation and progressive marginal tax rates have resulted in a higher tax burden, i.e., an inflation tax. In response to these higher tax rates, farmers have sought tax reduction strategies. The favorable corporate tax rates have made incorporation an attractive alternative, particularly for farm firms with large taxable

incomes. Moreover, inflation in asset values also has encouraged incorporation of farm firms to facilitate estate planning.

Integration and Coordination

The impact of inflation on integration and coordination of farm input-production-marketing activities is generated primarily through its effect on income variability. To the extent that inflation creates income instability, agricultural firms are likely to seek alternatives for alleviating or reducing such instability. Integrating production-marketing activities, use of the futures markets or cash forward contracts, and greater use of price forecasting services are all methods of reducing such instability. Diversification of farm firm enterprises and developing off-farm income are other alternatives for dealing with income variability. Although data is limited, it does appear that some of these risk-reduction strategies are gaining wider acceptance among farm firms.

Concluding Comments

Inflation influences the financial performance and structure of the farm sector by altering relative prices in factor and product markets. In the short run, income variability is increased because prices paid for production items respond more quickly to inflationary pressures than do prices received. In the long run, inflation alters income by reducing growth in productivity and the pricing efficiency of input and product markets. Yet, many questions about the effects of inflation on agriculture remain unanswered.

Research is needed to determine the inflation-induced changes in relative prices apart from supply-demand-induced changes in relative prices. There is also a need for better information on how inflation affects productivity increases in agriculture, nominal, and real net farm income, and the distribution of income and wealth. Research also is needed to determine inflation's impact on tenure patterns and other structural characteristics of agriculture.

Extension needs also are increased by increasing inflation. There is a need for information to help farmers deal with cash flow stress and other inflation-induced changes in financial conditions. There is also the need to make clear who gains and who loses from inflation. Inflation has also increased the need for extension information on acquisition and intergenerational transfers of capital assets.

Inflation has caused serious problems for the farm sector. But falling inflation rates also would create problems. For example, those who purchased assets expecting increased returns (fueled by inflation) to provide cash flows to service debt could be disappointed. In a less inflationary environment, many farm firms may be excessively leveraged. Finally, less inflation resulting in slower equity growth would leave new entrants or recently expanded businesses vulnerable to the adverse impact of nature-related risks for a longer period of time than if the expected rate of inflation had continued.

References

Eleveld, B. *The Impact of Increasing Input Prices on the U.S. Farm Sector: A Dynamic Simulation.* Tech. Rep. 79-3, Texas A&M University, Sep. 1979.

Friedman, M. "Inflation and Unemployment." *J. Polit. Econ.* 85(1977):466–67.

Lins, D. *Financial Condition of Agriculture: Past, Present, Implications for the Future.* Washington, D.C.: U.S. Department of Agriculture ESCS Staff Pap., June 1979.

Melichar, E. "Capital Gains versus Current Income in the Farming Sector." *Amer. J. Agr. Econ.* 61(1979): 1085–92.

Reimund, D. "Form of Business Organization." *Structure Issues of American Agriculture,* pp. 28–33. Washington, D.C.: U.S. Department of Agriculture ESCS Agr. Econ. Rep. 438, Nov. 1979.

Ruttan, V. "Inflation and Productivity." *Amer. J. Agr. Econ.* 61(1979):896–902.

Samuelson, P. *Economics,* 7th ed. New York: McGraw-Hill Book Co., 1967.

Schertz, L. *Another Revolution in U.S. Farming?* Washington, D.C.: U.S. Department of Agriculture, 1979.

Schultz, T. "Markets, Agriculture and Inflation." L.J. Norton Lecture Pap., University of Illinois, 11 June 1980.

Tweeten, L., and S. Griffin. *General Inflation and the Farming Economy.* Res. Rep. P-732, Oklahoma State University, Mar. 1976.

Tweeten, L., and L. Quance. "The Impact of Input-Price Inflation on the United States Farming Industry." *Can. J. Agr. Econ.* 19(1971):35–49.

U.S. Congress, Senate Committee on Agriculture, Nutrition, and Forestry. *Farm Structure.* Washington, D.C., Apr. 1980.

U.S. Department of Agriculture. *Agricultural Finance Outlook.* AFO-20, Washington, D.C., Nov. 1979a.

———. *Structure Issues of American Agriculture.* Agr. Econ. Rep. 438, Washington, D.C., Nov. 1979b.

Effects of Inflation on Financial Markets and Agricultural Lending Institutions

Danny A. Klinefelter, John B. Penson, Jr., and Donald R. Fraser

Inflation, one of the most misused words in the English language, is defined here as a continuing rise in the average level of prices for real goods and services. The following price changes thus do not constitute inflation: (*a*) a price increase for an individual good or service, (*b*) a once-and-for-all increase in the average level of prices, and (*c*) a temporary increase in the average level of prices. For example, a price increase for an individual good may affect the average price level. But by itself, this price increase is not inflationary since it is self-limiting; either producers will increase their production and hence drive the price down or else consumers will substitute for other goods in response to the higher price.

Inflation of the "steady pace" variety which can be forecasted with little or no error will have one set of effects on an economy. Inflation of the "fits and starts" variety which cannot be forecasted with a reasonably low error will have another set of effects. The generalization that inflation transfers wealth from lenders to borrowers, for example, is not valid if inflation can be forecasted with little or no error and if it can be fully reflected in interest rates. As Balbach points out, however, a monetary policy characterized by frequent changes in the rate of growth of the monetary aggregates will make it harder to forecast inflation, and hence lead to greater wealth transfers from lenders to borrowers than if these aggregates exhibited a stable growth pattern over time.[1]

Inflationary pressures in an economy can occur for a number of well-known reasons. For example, excessive growth in aggregate demand relative to aggregate supply will result in excess demand inflation. The growth in aggregate demand is influenced by macroeconomic policies that affect the growth in the monetary aggregates as well as taxes and government spending. Aggregate supply, however, is influenced more by the availability of labor and capital services than government policies in the short run. Thus, it is no wonder that an examination of the causes of inflation frequently starts with an analysis of recent macroeconomic policies to see if they have been overstimulating aggregate demand. Many analysts, for example, have concluded that excessive monetary expansion in the later 1970s, which had the effect of allowing us to pay for oil imports with cheaper dollars, is one of the major causes of recent inflation.

Having defined inflation and suggested one of its major causes in recent years, our task in this paper is to trace through the effects inflation has upon financial markets and the lenders providing loan funds to agriculture.

Effects of Inflation on Financial Markets

The impact of inflation on financial markets has been enormous. In the short period since 1966, U.S. financial markets have been devastated by periodic episodes of high and unstable rates of inflation. Moreover, with inflation has come high and extremely volatile interest rates that have intensified interest rate risk for participants in financial markets. Cyclical peaks in inflation and interest rates in 1966, 1969, 1974, and 1980 and the monetary and fiscal policy responses to these developments have substantially reduced the efficiency of financial markets. Long-term sources of funds for businesses, consumers, and governments during these periods not only became more expensive, but in many cases were unavailable at a reasonable price. Reflecting the acceleration of their costs, many lenders have recently sought to modify the terms of traditiona

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[1] This is not without its costs, however. The time spent managing these balances will cause a shift in the utilization of labor away from other activities.

contracts—bonds and mortgages—to protect themselves against declines in the purchasing power of their funds. Moreover, the behavior of financial institutions—the major participants in financial markets—is altered dramatically in an inflationary environment.

The impact of inflation on financial markets stems largely from the inability of market participants to anticipate correctly the rate of inflation over the life of the financial contract. If market participants accurately forecast future rates of inflation, nominal rates would adjust rapidly to changes in expected inflation and the real rate of interest would be constant.[2] The existence of an "efficient market" for information means that changes in expected inflation would neither benefit nor harm lenders and borrowers. However, given the underestimation of inflation rates in recent years, the real rate of interest realized by lenders (the nominal rate less the realized rate of inflation) frequently has been negative, which means that lenders have been subsidizing borrowers. This has led to an intense demand for loan funds and to savers becoming less willing to postpone consumption in order to provide loanable funds to lending institutions.

Reflecting the recent high and unpredictable inflation rates are the changes we have seen in the nature of financial instruments traded in financial markets. Lenders have become increasingly reluctant to subsidize borrowers with long-term fixed-rate contracts. The maturity of bonds and other fixed-income instruments has also been shortened. Moreover, lenders have sought to structure loan contracts where possible so that borrowers share a portion of inflation-induced profits with the lender. Examples of these "equity kickers" include requirements on loans for income-producing property that allow the lender to share in any unexpected increase in rental income from the property in addition to the interest payment. Borrowers also have sought to modify the terms of the traditional contract in response to inflationary trends. For example, at least one company has sought to reduce the interest cost of its borrowing activities by allowing the lender to redeem its bonds in a fixed number of units of a precious metal.

[2] This generalization is complicated by the fact that income taxes are levied on nominal rather than real interest and that a tax deduction is allowed on nominal interest payments rather than real interest payments. Given the present structure of the tax system, an increase in expected inflation would produce an even greater increase in nominal interest rates.

Perhaps the greatest impact of inflation has been on the mortgage market. The traditional long-term fixed rate mortgage has lost its viability in this type of environment. Increasing use has been made of the variable rate loan (Melton and Heidt). The variable rate mortgage, where the rate and/or maturity of the loan is automatically adjusted during the life of the loan, has become very popular in California and is spreading nationwide. In addition, the Canadian roll-over mortgage—rechristened the renegotiable rate mortgage—has been authorized for all federally chartered savings and loan associations. Under this latter type of mortgage contract, the maturity of the loan is short—generally three to five years—and the interest rate is renegotiated when it matures. Undoubtedly, other variants will be devised if inflation and interest rate risk remains high.

These changes have important implications for both borrowers and lenders. In recent years with the traditional fixed rate contracts, lenders accepted interest rate risk and thus suffered as inflation exceeded expectations. With shorter-term variable rate loans (and it is likely that variable rate lending will also come to the bond market), however, lenders are attempting to shift this risk to borrowers. Shorter-term contracts do, of course, substantially increase the need for liquidity management by borrowers. Moreover, they make borrowers more dependent upon lenders since the terms of the financial contracts must be negotiated more often. In addition, these new financial contracts may place a greater strain upon borrowers in periods of rapidly rising interest rates by lowering the expected value and increasing the variability of their investment returns.

Another way in which lenders have responded to the greater volatility of interest rates is by hedging in the financial futures market. It is no accident that trading in futures contracts for U.S. Treasury bills, notes, and bonds as well as commercial paper and Government National Mortgage Association pass-through certificates has developed at the same time that interest rate risk has increased. Indeed, the founding of the interest rate futures market in the early 1970s and its explosive growth in the late 1970s is directly attributable to the greater uncertainty in financial markets (Arar and McCurdy).

Inflation also has had a substantial effect on the nation's equity markets. It is not surprising

that equity prices have shown little gain in nominal terms (and a substantial decline in real terms) since inflation has become more pronounced. Equity values do, of course, represent the discounted present value of expected future cash payments. With inflation and higher interest rates, the applicable rate used to discount future cash flows is higher. Moreover, along with inflation has come greater variability of earnings and dividends. This greater variability, *ceteris paribus*, results in lower share values. In addition, recent data released by major corporations using Financial Accounting Standards Board guidelines for reporting inflation-adjusted financial statements suggest that actual earnings have been well below those reported to shareholders and that many firms have paid out more than their current earnings in cash dividends.

The response of economic stabilization policies to inflation has further implications for the nation's financial markets. As inflation accelerates cyclically, stabilization policy—especially monetary policy—seeks to "lean against the wind" by restricting the availability of credit. Not only do interest rates rise in these periods, but there is also a sharply diminished availability of funds to particular sectors of the economy, like the housing sector and to small businesses in general. Moreover, it is during these periodic "credit crunches" that financial innovations such as money market funds occur that have had such a profound impact on the structure of the U.S. financial system.

Effects on Agricultural Lending Institutions

In addition to affecting financial markets, inflation also affects the lending activities of institutions providing loan funds to agriculture. In examining these effects, we shall separate those factors that affect the demand for loan funds from those factors that affect supply.

Effects on Demand for Loan Funds

The demand for loan funds in agriculture in recent periods of inflation has been affected in several different ways. First, anticipated inflation reflected in higher interest rates charged producers has increased the cost of financing annual production expenses and capital expenditures, thereby lowering nominal net farm income.

Second, the purchasing power of net farm income is lowered in an inflationary environment. And, because net farm income is taxed in nominal rather than real dollars, the current real savings of producers is further reduced.

Third, expectations about future relative prices and interest rates also influence annual investment decisions and hence the demand for loan funds (Fama; Levi and Makin). For example, a producer considering the purchase of a new piece of equipment must form expectations about future cash receipts and expenses as well as the relevant marginal income tax rate. In the case of land, the producer must also form expectations about the capital gains income on this investment and the capital gains tax rate. If relative prices can be forecasted with a reasonably low forecast error, the producer may well rationalize he is better-off going ahead with investment projects now rather than waiting and paying a higher purchase price later. However, higher forecast errors and correspondingly higher risk-adjusted required rates of return may well mean some projects are no longer acceptable.

Fourth, the expectation of future increases in land values has had the positive effect in agriculture of increasing the nominal net worths of those who own land. These unrealized capital gains often collateralize loans to finance short- and intermediate- as well as long-term uses of funds. But, rising debt levels in agriculture, coupled with lower nominal net farm incomes, underscore the increased exposure to financial risk for both borrowers and lenders and the increasing burden placed upon future income to retire debt.

Finally, inflation has brought with it uncertainty about future government policies. This greater uncertainty pertains not only to those policies that address the need for deficiency payments and economic emergency loans to producers in agriculture, but also to those monetary and fiscal policies that affect the cost and availability of loan funds as well as the level of income and social security tax payments (Balbach).

Effects on Supply of Loan Funds

Of the financial institutions providing loan funds to agriculture, commercial banks appear to be the most affected by inflation. This impact is evident in four areas: (*a*) legal lending limits, (*b*) usury ceilings, (*c*) the availability of loan funds, and (*d*) funds management.

The problem of legal lending limits per borrower has increasingly handicapped rural banks in financing producers. The problem is directly related to bank structure and is most constraining in unit banking states. Since legal lending limits are based upon the size of a bank's capital and surplus, increasing farm size and greater use of purchased inputs increasingly cause loan requests to exceed bank legal lending limits. The problem becomes acute in periods of inflation in agriculture because input costs tend to rise faster than product prices, which translates into an increased demand for loan funds and slower loan repayment.

Usury ceilings have created problems for banks in three ways. First, these ceilings tend to divert funds away from areas subject to usury ceilings, which in many states includes loans to farm proprietors. Second, bank profits are reduced, which further decreases the ability of banks to make loans by limiting the growth of their capital and their ability to attract deposits. Third, banks have experienced a loss of market share, particularly to the Farm Credit System and government lending agencies. Banks have had to restrict their loan funds in periods of high rates while their competition has been unconstrained by state usury ceilings. These competitors are also not required to hold a portion of their sources of funds in reserve.

The Monetary Control Act of 1980 overrode state usury laws for agricultural loans exceeding $25,000. However, two problems still exist. First, some farm loans are made that do not exceed this amount. While banks will consolidate a borrower's loans as the total reaches $25,000, some loans initially will be subject to usury ceilings. As a result, smaller producers requiring only operating funds may still find loan funds restricted when market interest rates are increasing. Second, this provision expires on 1 April 1983, or earlier if ceilings are reinstated by the state (American Bankers Association).

Limited availability of loanable funds at banks often reflects the fact that deposits are growing at a slower rate than the demand for loan funds. Although this problem tends to be both regional and cyclical in nature, projection of further increases in the use of debt by producers indicates this problem will persist. Moreover, because of their size and market area, rural banks are not in a position to bid for funds in the national money market. And the growth in the popularity of money market funds has accentuated the drain on deposits in many smaller banks into major money center banks.

To counteract the problem of loan fund availability, banks have been forced to increase their use of correspondent bank and PCA participations, to create agricultural credit corporations which either sell commercial paper or discount loans with Federal Intermediate Credit Banks, and to use bankers acceptances placed through city correspondents. They also have attempted to stem the outflow of deposits by offering money market certificates of deposit. The 17 April 1980 action of the Federal Reserve to make it easier for small banks to utilize the "seasonal borrowing privilege" and the provisions of the Monetary Control Act to allow access to the discount window for nonmember banks are other examples of responses to the shortage of loanable funds at rural banks.

Cyclical fluctuations in market rates on government securities in an inflationary environment also affect bank liquidity by increasing the cost of converting securities into loanable funds to meet loan demand. As interest rates rise and security prices fall, banks would suffer capital losses if they sold these securities to generate loanable funds. The problem of loan fund availability is also compounded by the fact that the higher rates on securities and other investment alternatives often make them more attractive than loans, particularly when usury ceilings and credit restraint programs exist.

Serious funds management problems have been a relatively recent phenomenon for rural banks. Although the introduction of money market certificates has allowed them to stem losses of deposits, the certificates have not produced a net inflow of funds to rural banks. Because the rates on these certificates are tied to new U.S. Treasury issues, many rural banks are for the first time experiencing the problems associated with managing purchased money and reflecting these costs in their loan-pricing and fund allocation decisions. This environment is further aggravated by the phasing out of Regulation Q, the payment of interest on transactions accounts and the fixed interest rates banks have traditionally charged on loans. Now banks find that both costs and revenues are fluctuating, which creates decision situations for a management that is often ill-equipped to handle them. It is not surprising

therefore that there has been a dramatic growth in holding company acquisitions in those states which allow multiple bank holding companies.

In contrast to commercial banks, the Farm Credit System obtains its funds from the national money market and thus far has not been faced with a reduced availability of loanable funds. The cost of these loanable funds, of course, increases as interest rates rise. But, because the Farm Credit System is exempt from state usury laws and uses a variable interest rate program, it is able to pass these increased costs on to their borrowers. Moreover, the Farm Credit System has not been limited by legal restrictions on the size of a loan to any one borrower.

While the Farm Credit System has experienced relatively low levels of delinquency, cyclically increasing inflation rates tend to increase its exposure to risk. To a large extent, farm borrowing has been collateralized by unrealized capital gains stemming from rising land values. Producers have thus been able to refinance short-term debt on a longer-term basis when farm incomes have fallen. As a result, however, the Farm Credit System is more than ever dependent upon land values continuing to appreciate rather than depreciate.

The fastest growing source of loan funds to producers in recent years has been government lending agencies like the Commodity Credit Corporation, the Farmers Home Administration, and the Small Business Administration. The Commodity Credit Corporation, which was not a market factor during the early 1970s, has again become a major source of funds because commodity prices have fallen below loan rates. The nonrecourse provision of these loans, the subsidized nature of their interest rates, and the option to extend the loan on stored commodities has made CCC lending programs increasingly attractive to producers, both from a marketing standpoint as well as a financing standpoint. The fixed rate feature of these loans is also attractive as is the downside price protection provided by the loan rate, the removal of the set-aside provision and the ability of producers to now place their entire crop under loan. Unless market conditions improve dramatically, the CCC loan program will continue to account for an increasing share of the market.

The greatest growth in agricultural loans made by the Farmers Home Administration and Small Business Administration has been in the area of emergency and disaster loans. Because an economic emergency can occur for reasons other than natural disaster (such as a general tightening of credit or unfavorable income levels), monetary policies which raise interest rates and restrain credit in the private sector cause producers to turn to government lending agencies. These emergency loan programs are also not as restrictive in terms of loan limits as are the normal operating and farm ownership loan programs. In some instances, these programs have encouraged production and further capitalization in high risk areas.

The impact of inflation has also been enormous on the other institutional sources of debt financing. Life insurance company loans and merchant-dealer credit virtually stopped during the most recent surge in inflation and interest rates. Since the mid-1960s, the life insurance company share of the farm real estate debt market has declined in each of the cyclical peaks of inflation. As sources of consumer credit shrink and interest rates rise, many policy holders borrow against the loan values of their policies, thereby cutting into life insurance company investable funds. Like commercial banks, usury limits have forced life insurance companies to divert funds to areas where earnings rates are not artificially restricted. The decline in farm incomes and the slowing in the growth rate of farm land prices have tended to make agricultural loans less attractive from a risk standpoint, particularly when better, more stable yields are available on other investments.

Merchant-dealer credit also tends to contract as inflation rates increase. The cost of acquiring loanable funds reduces the profitability of extending credit for the credit subsidiaries of manufacturing firms. Moreover, retailers are forced to tighten their credit policies as the cost of carrying customer accounts increases.

Potential Issues

If the U.S. economy continues to be plagued by periods of high and variable rates of inflation, there will be both enormous impacts on the flow of funds in agriculture and significant research opportunities. For example, what are the structural implications of continued variable inflation rates for the lenders serving ag-

riculture? What about the government lending agencies and the Farm Credit System? Will they be able to accommodate an increasingly larger share of the market? What effect would a policy change that significantly reduced the government's involvement in agricultural lending have upon borrowers and nongovernment lenders? If the Farm Credit System continues to account for larger and larger market shares, will it affect their ability to acquire funds in the nation's financial markets and the cost of these funds?

There are also some significant implications for the commercial banking industry. What are the potential effects on how agriculture is currently financed if the ownership of banks becomes more concentrated in bank holding companies which are headquartered in the major money centers? We must also consider the potential structural effects of interstate banking. Many of these trends are already underway. However, they will probably be accelerated if the instability associated with the current inflation picture continues. There are also other important issues relating to the impacts of the 1980 Monetary Control Act, including how monetary policy is transmitted. Three areas of this Act appear to have a particular impact on rural banks: (*a*) the effects of expanding Federal Reserve authority to cover nonmember state banks, (*b*) the effects of phasing out of Regulation Q and the introduction of interest-bearing transactions accounts on the already serious funds management problems confronting rural bank management, and (*c*) the potential changes in the availability of loan funds due to the override of state usury ceilings.

Although much has been written about rational and inflationary expectations, more needs to be done before we are in a position to understand what factors producers consider when forming expectations about the variability and levels of future relative prices and yields. Expectations of relative prices and their variability, for example, are major determinants in the decision-making process of producers, and influence both their investment decisions as well as their demand for loan funds. The extent to which these expectations are transmitted into asset values will also affect the risk position of lenders accepting these assets as collateral for new loans.

A better understanding of how to forecast more accurately future prices and their variability may help lenders better anticipate future inflation and their exposure to risk and to reflect these effects in their interest rates. From the mid-1960s until recently, for example, inflation rates have often greatly exceeded expectations, thus resulting in a transfer of wealth from lenders to borrowers. The greater use of variable interest rates and terms by lenders is aimed at minimizing this wealth transfer in the future. What effect a complete switch to variable rates and terms on loans and bonds will have upon the flow of funds in these financial markets, however, remains to be seen.

References

American Bankers Association. "The 1980 Bank Deregulation Law." *Capital,* 8 April 1980.

Arar, Marcelle, and Christopher J. McCurdy. "Interest Rate Futures," Federal Reserve Bank of New York *Quart. Rev.,* 4(Winter 1979–80):33–44.

Balbach, Rachel. "The Effects of Changes in Inflationary Expectations." Federal Reserve Bank of St. Louis *Review,* 59(1977):17–26; reprinted in *Federal Reserve Readings on Inflation,* pp. 185–9. New York Federal Reserve Bank, 1979.

Fama, Eugene F. "Interest Rates and Inflation: The Message in the Entrails." *Amer. Econ. Rev.* 67(1977):487–96.

Levi, Maurice D., and John H. Makin. "Anticipated Inflation and Interest Rates: Further Interpretation of Findings on the Fisher Equation." *Amer. Econ. Rev.* 68(1978):801–17.

Melton, William C., and Diane L. Heidt. "Variable Rate Mortgages." Federal Reserve Bank of New York *Quart. Rev.,* 4(Summer 1979):23–31.

Inflation Effects on Farm Financial Management

Fred C. White and Wesley N. Musser

The issue of financial management under inflation is a relatively new topic for agricultural finance research. Research in this area traditionally has focused on inflation issues such as land price increases, capital gains in agriculture, and trends in farm prices and costs with an emphasis on aggregate issues rather than firm management. Firm growth research considered inflation, but it was not the major focus of such research (Brake and Melichar). This limited firm research can be related, in part, to the explicit exclusion of inflation in the net present value concept, which is a major theoretical foundation for financial management. This shortcoming has been overcome recently. Aplin, Casler, and Francis were the first to consider explicitly the impact of inflation on net present value calculations in their agricultural finance text, and subsequent texts have done likewise (Barry, Hopkin, Baker; Penson and Lins).

This paper has as its major purpose the review of recent developments in finance theory related to the consideration of inflation in a net present value framework. While an exhaustive presentation of the implications of these theoretical models for agricultural firm management is impossible, major methodological and empirical directions for future research are recognized. Theoretical and/or empirical consideration of particular issues, such as optimal replacement decisions, estate management, firm growth, income tax management, leasing versus purchase, optimum capital structure, and operating leverage, would have been beyond the scope of this paper.

Net Present Value Formulation under Inflation

The net present value (NPV) criterion is widely used to analyze projects that generate cash flows through time. While the NPV principle appears simple in concept, its application under inflation requires some modifications in standard methodology used for situations without inflation. Conditioned by years of relative price stability, the standard practice has been to estimate current cash flows and to use current interest rates as an estimate of the discount rate. Future revenues and costs in other studies have often been valued at current prices, implicitly assuming no inflation. With the emergence of inflation, this practice will result in a bias in NPV, possibly indicating rejection for some desirable investments (Van Horne). In modifying the NPV formulation to account for inflation, it is important to adjust both cash flows and the discount rate.

Cash Flows

All cash flows, especially in agriculture, are not expected to inflate at the same rate as the inflation rate in the general economy. Thus different inflation rates should be utilized for different cash flows. Cooley, Roenfeldt, and Chew explicitly incorporate such assumptions in an NPV model. A simple analytical method of accounting for the differential impact of inflation in NPV is to specify net operating income (NOI) as follows:

$$(1) \qquad X_j^i = X_j^0\ (1 = i\lambda)^j,$$

where X_j^i is NOI before taxes in year j with general inflation rate of i, X_j^0 is NOI before depreciation and taxes in year j without inflation, i is annual inflation rate, and λ is a measure of NOI sensitivity to inflation.

The next step in adapting the NPV concept is to give explicit attention to income taxes in the cash flows (R_j). An after-tax basis formulation of R_j can be defined as

$$(2) \quad R_j = X_j^i\ (1 - T_j) + T_jD_j = X_j^0\ (1 + i\lambda)^j(1 - T_j) + T_jD_j$$

where T_j is the marginal tax rate in year j, and

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D_j is the depreciation allowance in year j. Because tax law fixes the tax savings on depreciation, T_jD_j, that portion of R_j should not be subjected to inflationary trends. Cooley, Roenfeldt and Chew also note that components of cash receipts and expenses that are fixed in price for the life of the investment through long-term contract also will not be subjected to inflation.

The cash flows generated by the salvage value of the asset at the end of the planning horizon can be treated similarly to R_j. The salvage value of the asset S^0 without inflation must be adjusted to reflect inflation. It is assumed that S^0 inflates at an annual rate of $i\gamma$ where γ is the salvage value's sensitivity to inflation. The appropriate salvage value at the end of the planning horizon is $S^0(1 + i\gamma)^n$. However, a tax effect also results from the sale if $S^0(1 + i\gamma)^n \neq C_0 - \sum_{j=1}^{n} D_j$, where C_0 = the initial purchase cost. If $S^0(1 + i\gamma)^n \leq C_0$, any tax effects can be treated as ordinary income. However, if $S^0(1 + i\gamma)^n > C_0$, a capital gains tax liability is incurred. For nondepreciated assets such as land, inflation will result in capital gains tax liability. However, inflation increases the possibility of capital gains even for depreciating assets, particularly when rapid depreciation methods are used for taxes.

The terminal cash flows after taxes, Q, can be summarized as follows:

$$(3) \quad Q = S^0(1 + i\gamma)^n - T_n\,(gG) - T_nP,$$

where G is capital gain, g is proportion of taxable capital gain, and P is ordinary taxable income resulting from the sale. In the case when $G > 0$, $P = \sum_{j=1}^{n} D_j$. If $G = 0$, $P = S^0(1 + i\gamma)^n - C_0 + \sum_{j=1}^{n} D_j$. It can be noted that a tax savings results from the sale if $S^0(1 + i\gamma)^n < C_0 - \sum_{j=1}^{n} D_j$ so that $P < 0$ and the third term of (3) is positive.

Discount Rate

Following Fisher, the real cost of capital k_j is generally assumed to be invariant with inflation. Since income taxes are included in cash flow formulation in (2), k_j is defined as an after-tax cost of capital (Adams). In addition, k_j is a weighted average cost of capital rather than a target internal rate of return since debt service charges are not included in the cash flows in (2) (Plaxico and Kletke). Formally, k_j is defined as

$$(4) \quad k_j = k_e(1 - T_j)\,(1 - L) + r(1 - T_j)\,(L),$$

where k_e is the before tax cost of equity funds, L is the ratio of debt to assets in the capital structure, and r is the effective cost of debt.

The nominal discount rate d_j is derived by multiplying the real rate, $1 + k_j$, times $(1 + i)$:

$$(5) \quad d_j = (1 + k_j)\,(1 + i) = 1 + k_j + i + ik_j.$$

It can be noted that d_j is not simply the sum of the real discount rate plus the rate of inflation as is commonly assumed (Harris). Admittedly, the correction factor ik_j is quite small in a situation of relative price stability but could be significant for analysis of a combination of high values of i and k_j.

Two approaches could be used to estimate nominal discount rates. One method is to assume discount rates which were observed historically during periods with similar inflation rates as assumed for the cash flows. Harris and Nehring and Lee and Rask are good examples of this approach, except that they used an internal rate of return for a discount rate rather than a weighted average cost of capital. The other method is to estimate k_j for periods when prices were relatively stable and then use (5) to estimate the discount rate. This method would be appropriate for example to analyze inflationary trends larger than have existed historically. To use this approach one must use data during the last sustained period of relative price stability when the interest rates for agricultural loans were between 4% and 6%. Some readers may find the previous work of the authors on estimating weighted average cost of capital helpful for both approaches (White, Musser, Oosthuizen).

A final point which deserves emphasis is the treatment of risk in the discount rate. If R_j in (2) is considered the expected value of cash flows, then both k_e and r in (4) are a sum of a time preference component and a risk premium. Cooley, Roenfeldt, and Chew stress that risk premiums for inflation be added to k_j when nominal rates such as in (4) are used. Their view is based on the proposition that inflation rates cannot be perfectly anticipated. Cooley, Roenfeldt, and Chew also suggest that (5) only be used to discount X_j^i and a nearly risk-free rate be used to discount T_jD_j because

the tax savings will be earned as long as taxable income is positive. However, this procedure is not consistent with the conventional methods of estimation of k_j which do not separate T_jD_j from the remainder of R_j and is therefore not adopted in this paper.

Net Present Value

Using the concepts developed previously, the relationships in equations (2), (3), and (5) can be used to create a basic NPV formula under inflation:

$$(6)\quad NPV = \sum_{j=1}^{n} \frac{X_j^0(1 - T_j)\,(1 + i\lambda)^j + T_jD_j}{(1 + k_j)^j\,(1 + i)^j} + \frac{S^0(1 + i\gamma)^n - T_n gG - T_n T}{(1 + k_j)^n\,(1 + i)^n} - C_0.$$

Except for the complicating effects of inflation, (6) is used to analyze investment in the same manner as conventional formulas. If $NPV > 0$, the investment should be accepted if it is independent of other alternative investments. For mutually exclusive investments, the project with the highest value of NPV should be selected.

Inflationary Impacts of Investments

Examination of (6) readily indicates that inflation affects NPV and therefore the investment process. Inflation does not have a neutral effect on NPV for three reasons: (*a*) the sensitivity coefficients λ and γ are not equal to one, (*b*) the noninflating values of D_j, and (*c*) income tax liabilities generated by the salvage value of the asset. Consideration of the impact of inflation on NPV would require theoretical and/or empirical analysis of the special cases of these three factors, especially the third.

To illustrate the possible theoretical analysis, a simple case where $S^0(1 + i\gamma)^n = G = P = 0$, and tax rates are indexed for inflation ($\partial T_j/\partial i = 0$) is useful for analytical and expository ease. Under these assumptions, (6) can be simplified as follows:

$$(7)\quad NPV = \sum_{j=1}^{n} \frac{X_j^0(1 - T_j)\,(1 + i\lambda)^j}{(1 + k_j)^j\,(1 + i)^j} + \sum_{j=1}^{n} \frac{T_jD_j}{(1 + k_j)^j\,(1 + i)^j} - C_0.$$

Differentiating (7) with respect to i yields

$$(8)\quad \frac{\partial NPV}{\partial i} = \sum_{j=1}^{n} \cdot \frac{jX_j^0(1 - T_j)\,(1 + i\lambda)^j[\lambda(1 + i\lambda)^{-1} - (1 + i)^{-1}]}{(1 + k_j)^j\,(1 + i)^j} - \sum_{j=1}^{n} \frac{j(1 + i)^{-1}\,T_jD_j}{(1 + k_j)^j\,(1 + i)^j}.$$

First considering the case in which $\lambda = 1$, the first summation is zero because the term in brackets is zero. The value of the derivative would be negative because the only remaining term, the last summation, is preceded by a negative sign. With X_j^0 inflating at the same rate as the general inflation rate, the real value of the discounted cash flows are not affected. However, constant nominal tax savings will result in declining real values for the second term and therefore decreasing NPV. In this case, some investments will not be viable with inflation that would have been viable with stable prices. This relationship is consistent with the general finding that use of historical costs rather than current replacement costs as the basis for depreciation depresses investment (Nelson, Lintner, Hong).

A more interesting case results when $\lambda \neq 1$. Because the mathematics are quite tedious, they will not be presented, but are available from the authors for interested readers. A summary of this case is that NPV decreases even more than when $\lambda = 1$ if $\lambda < 1$. However, NPV can increase with inflation if λ is sufficiently larger than one. The intuitive interpretation of these results is that inflation increases the viability of many investments in sectors with profitability trends well above the average and severely depresses investment when profitability trends are less than the average inflation rate. Agriculture usually tends towards the latter case except in situations of high export demand and/or random reductions in production.

The theoretical model in (6) can be used to examine other interesting impacts of inflation. One general source of propositions is to differentiate $\partial NPV/\partial i$ with respect to one of the other parameters in (6). The authors have investigated the case of zero salvage value and terminal taxes with these methods. For the sake of brevity, these results will be summarized without the mathematics.

Depreciation

What is the impact of inflation on investments with higher levels of depreciation relative to operating income? The general answer to this question is that the higher the ratio of D_j to X_j^0, the larger the reduction in NPV due to inflation. Assets whose R_j contains more depreciation will therefore be impacted more by inflation. Land would be least impacted by inflation under this proposition. In addition, accelerated depreciation may help to mitigate the impact of inflation.

Marginal Tax Rate

Studies of inflationary impacts in the finance literature have been concerned with corporations for which the marginal tax rate can be assumed constant. For farm firms, exploration of the differential effects of the marginal tax rate allows consideration of the structural impact of inflation. As with many tax issues, the theoretical results are not very intuitive and in this case depend on the value of λ. If $\lambda \geq 1$, higher marginal taxes will have a negative effect in the change in NPV due to inflation. In beneficial periods of inflation for agriculture, farmers with the lower tax bracket will experience the greatest increase in NPV; and, in the opposite case, these individuals will also experience the most decrease in NPV.

Discount Rate

As with the tax rate, the results with respect to different levels of k_j depend on λ. If λ is less than the value such that $\partial NPV/\partial i > 0$, a higher discount rate results in a smaller decrease in NPV. If the λ is larger, a higher discount rate results in a smaller increase in NPV.

Other Important Issues

Several other important issues in financial management could have been considered in this paper. Since other papers have recently considered these issues, the decision was made to de-emphasize these issues. However, summaries of the results may be helpful to some readers. Bates, Rayner, and Custance recently considered the effect of inflation on optimum replacement. Their conclusion was that inflation increased the optimal replacement age. A corollary to this result is that inflation would encourage investment in durable assets with a longer life; on this point, it can be noted that Nelson made a theoretical mistake on this issue. Several other issues are the effects of inflation on equity and growth, and use of leverage under inflation, which Robison and Brake have recently considered. Inflation increases liquidity problems and slows growth. In addition, leverage is beneficial under unanticipated inflation in that the interest rates do not compensate the lender for loss of wealth. However, if the interest rates correctly anticipate inflation, no unintended effects of inflation occur (Hong). It can be added that realized inflation rates less than anticipated in the interest rates will have the opposite effect—some farmers may experience this situation in 1980.

Conclusions

This research has examined the theoretical consequences of inflation on financial management decisions of farmers. From the issues considered, it is evident that inflation is likely to have a significant impact in the area of financial management. In essence, the findings indicate that the investment decision is not neutral with respect to the rate of inflation even if nominal net operating income adjusts with inflation because nominal tax savings from depreciation do not adjust. The net present value of these future cash flows would thus decline with inflation and reduce the incentive to invest. This result differs considerably from the common proposition that NPV is invariant with inflation.

While the net present value formulation developed in this paper is a generalization of previous models, its interpretation was based on several simplifying assumptions: (*a*) market and tax salvage values of the asset at the end of its economic life were assumed zero, (*b*) the rate of inflation is constant over time, and (*c*) marginal tax rates are indexed for inflation. Relaxing these assumptions would complicate the analysis, because the impact of these interrelationships is complex. Further theoretical and empirical analysis is necessary to interpret these interrelationships. Because of the complex interrelationships, use of financial management theory will be helpful, if not necessary, to interpret empirical research.

The model to evaluate investment alterna-

tives under inflation presented in this paper was developed in the context of normative firm analysis. Application of the model would indicate whether or not a particular investment opportunity was economically feasible and should be undertaken. This model also could be used as a framework for positive analysis of investment in agriculture. An empirical analysis of the various components of the model should provide a basis to predict changes in agricultural investment in response to changes in various exogenous factors such as the rate of inflation and tax laws. One definite conclusion of this paper is that inflation should be included as a causal variable in investment models.

References

Adams, Roy D. "The Effect of Income Tax Progressivity on Valuations of Income Streams by Individuals." *Amer. J. Agr. Econ.* 59(1977):538–42.

Aplin, Richard D., George L. Casler, and Cheryl P. Francis. *Capital Investment Analysis Using Discounted Cash Flows*, 2nd ed. Columbus, Ohio: Grid, 1977.

Barry, Peter J., John A. Hopkin, and C. B. Baker. *Financial Management in Agriculture*, 2nd ed. Danville, Ill.: Interstate Publishers, 1979.

Bates, J. M., A. J. Rayner, and P. R. Custance. "Inflation and Farm Tractor Replacement in the U.S.: A Simulation Model." *Amer. J. Agr. Econ.* 61(1979):331–34.

Brake, John R., and Emanuel Melichar. "Agricultural Finance and Capital Markets." *Survey of Agricultural Economics Literature*, vol. 1, ed. Lee R. Martin. Minneapolis: University of Minnesota Press, 1977.

Cooley, Phillip L., Rodney L. Roenfeldt, and It-Keong Chew. "Capital Budgeting Procedures under Inflation." *Finan. Manage.* 4(1975):18–27.

Fisher, Irving. *The Theory of Interest.* New York: Macmillan Co., 1930.

Harris, Duane G. "Land Prices, Inflation, and Farm Income: Discussion." *Amer. J. Agr. Econ.* 61(1979):1105–6.

Harris, Duane G., and Richard F. Nehring. "Impact of Farm Size on the Bidding Potential for Agricultural Land." *Amer. J. Agr. Econ.* 58(1976):161–69.

Hong, Hai. "Inflation and the Market Value of the Firm: Theory and Tests." *J. Finan.* 32(1977):1031–48.

Lee, Warren F., and Norman Rask. "Inflation and Crop Profitability: How Much Can Farmers Pay for Land?" *Amer. J. Agr. Econ.* 58(1976):984–90.

Lintner, J. "Inflation and Security Returns." *J. Finan.* 30(1975):259–80.

Nelson, Charles R. "Inflation and Capital Budgeting." *J. Finan.* 31(1976):923–31.

Plaxico, James S., and Darrel D. Kletke. "The Value of Unrealized Farm Land Capital Gains." *Amer. J. Agr. Econ.* 61(1979):327–30.

Penson, John B., Jr., and David A. Lins. *Agricultural Finance*. Englewood Cliffs, N.J.: Prentice-Hall, 1980.

Robison, Lindon J., and John R. Brake. "Inflation, Liquidity and Growth: Some Implications for the Farm Firm." Paper presented at Southern Agricultural Economics Association meeting, Hot Springs, Ark., 3–6 Feb. 1980.

Van Horne, J. "A Note on Biases in Capital Budgeting Introduced by Inflation." *J. Finan. Quant. Analysis*, Jan. 1971.

White, Fred. C., Wesley N. Musser, and Johannes Oosthuizen. "Cost of Capital for American Agriculture: Its Use in Agricultural Policy Formation." *Agr. Finan. Rev.* 38(1978):21–28.

Inflation and Agricultural Finance: Discussion

Lindon J. Robison

On my high school football team was a large, slow defensive guard who sat on the bench most of the time while a smaller, more agile fellow enjoyed the action. In response to town-folk criticism about his personnel deployment, my coach responded: "I'd rather get there with a little than not get there with a lot." I will try to follow that prescription by focusing on one point which appeared in all three of these interesting papers. This lack of attention to the many other points in the papers should not be construed as agreement or disagreement, only a lack of time and space to respond.

Klinefelter, Penson, and Fraser began their paper with a review of inflation-causing factors and lender responses to greater and more uncertain inflation, such as shorter-term loans and variable or renegotiable interest rates. The best example of this response to uncertain inflation has been the Farm Credit System's adoption of variable interest rates as early as the late 1960s.

It should be evident that adopting variable interest rates and renegotiable rates result in all borrowers paying a more nearly equal rate. Moreover, if cost to borrowers is based on a weighted cost of funds obtained by the lenders, such as is the case with the Farm Credit System, interest rates will respond rather sluggishly to inflationary (deflationary) pressures. This suggests that, as all three papers appear to agree, inflation has differing impacts over time on input and output prices received by farmers. I will return to the implication of this point later.

Lins and Duncan discuss more explicitly the point made earlier. Inflation does not affect all prices equally, although for the unfortunate farmers, prices paid appear to respond more to upward pressures than prices received. But lacking from Lins' table of correlations was the correlation with interest rates. If interest rates equal a real rate of interest, say between 3% to 5%, and the rest equals an inflationary premium, then credit up to now may contradict Lins and Duncan's general statement that input costs rise more rapidly than output prices.

The impact of all this, Lins and Duncan hypothesize, is fewer but larger farms, a move to organize farm organizations as corporations, and vertical integration. Unfortunately, neither they nor I have time to explore these hypotheses.

White and Musser attempt to "equationize" the points already identified in the two earlier papers. They introduce a capital budgeting model which explicitly allows for differing inflationary impacts on the discount rate and net returns. Since, as Klinefelter, Penson, and Fraser point out, capital assets equal the discounted present value of their returns, Musser and White's approach appears justifiable and their conclusion that increasing inflation reduces net present value is reasonable. Moreover, they recognize, as do Lins and Duncan, that cash flows will not necessarily inflate at the same rate as inflation in the general economy.

Having identified the same point in all three papers, it seems that a statement about the effects of differing inflation rates is needed. I provide one. (See also Melichar.)

Let V be the price of a nondepreciating capital asset in a noninflationary economy which earns R net returns for n periods and is sold n periods later for the same price V. In addition, let r be the time preference rate which discounts both R and V to a present value. The relationship between R, V, and r is the familiar capitalization formula, V equals R/r.

Now, introduce inflation, which increases income and the capital asset s value in each period by $g\%$ and the discount rate by $i\%$ in each period.

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$$(1)\qquad V = \frac{R(1+g)}{(1+r)(1+i)} + \dots + \frac{R(1+g)^n}{(1+r)^n(1+i)^n} + \frac{V(1+g)^n}{(1+r)^n(1+i)^n}.$$

The result, after geometrically summing income, is a modified capitalization formula equal to

$$(2)\qquad V = R(1+g)/(r+i+ir-g).$$

Now, if g equals i, that is, both income and the discount rate are affected equally by inflation (in White and Musser's notation $\lambda = 1$), then V, of course, again equals R/r and V increases in each period by the inflation rate i.

The direction of the change in V, as i and g change, is apparent. The point to be emphasized is the magnitude of change. To illustrate, begin with a noninflationary economy and let g increase from zero to 1%. The result is a 25% increase in V. In contrast, a 1% increase in i (the discount rate) reduces V by 17%. Small wonder then, when interest rates (the discount rate) skyrocketed the first part of 1980, Iowa farmers were reporting land value declines of up to 10%.

Lins and Duncan quoted Samuelson who said: "the problem with inflation is not so much price increases, but rather the inefficiencies caused by changes in relative prices," to which we might add, that the problem with inflation is not so much that prices increase, but rather that they do so unequally.

Reference

Melichar, Emanuel. "Capital Gains versus Current Income in the Farming Sector." *Amer. J. Agr. Econ.* 61(1979):1085–92.

Inflation and Agricultural Finance: Discussion

Eddy L. LaDue

It is obvious from reading or listening to these three papers that the authors' primary goal was to summarize, or at least indicate, the current level of knowledge of our profession relative to the impact of inflation on agricultural finance. This is a useful effort and they did a good job; but, if you accept that as their goal, you have to be impressed with how little we know. The really disappointing aspect of these papers was their nearly total lack of extension of our knowledge in this area. This is not unusual for invited paper sessions, and no research money comes with the invitation to prepare a paper, but, given the outstanding capacities of the individuals involved and the paucity of real knowledge in the area, I had hoped for more. The papers do provide a good basis for discussion.

White and Musser do a good job of mathematically incorporating inflation into the simple net present value model for investment evaluation. The interaction between inflation and the revised model is then used to look at a few factors in the model for an exceptionally simple investment situation. The pedagogically useful simple mathematical specification is the main contribution of the paper. All of the inflation-related characteristics contained in the model have been in use in operational extension models for five years (LaDue and Casler). In developing and using the model Casler and I developed in 1975, we have observed a number of problems, at least some of which might be considered deficiencies in the White-Musser model. These are:

(*a*) Representation of taxes must be more complete. Investment credit and the progressive tax structure that most farmers face must be included. White and Musser imply use of an iterative process to get income and the marginal tax rate consistent, but this is a burdensome procedure. The biggest problem with taxes is that they are paid on nominal income, are not indexed, and we have little knowledge of when future tax cuts will occur. We need to know the relative impact of indexing versus the irregular stair-stepping tax levels through time brought about by periodic tax cuts.

(*b*) Most major investments require non-year-zero capital expenditure either to complete the investment or to replace part of the investment which has a life less than the planning horizon used in analysis. Inflation is not neutral relative to these investments.

(*c*) Usefulness of the model is dependent on quality of inflation estimates. When components are considered separately, it is easy for farm operators and professors unintentionally to develop estimates that imply a relative change in the profitability of agriculture which the people making the estimate do not actually expect. Operationally, we find that it is hard for farmers to specify aggregate impact of inflation. It is much easier to think about inflation of individual items or components.

The greatest shortcoming of this paper is its narrow nature; under the title of "Inflation Effects on Farm Financial Management," the actual financing of investments is left to one sentence. My analyses to date (LaDue 1979) lead me to believe that the greatest potential impact of inflation on individual farms is the cash flow impact of financing, as was pointed out by Lins and Duncan. Certainly this implies financial management problems for a great number of farmers and may lead to the need for changes in financial arrangements used by all lenders but in particular the arrangements offered by public lenders such as FmHA. For example, would graduated payment mortgages allow beginning farmers to compete more effectively for farm assets?

As indicated in both of the other papers, an impact of recent inflation has been to shift the interest rate risk from lenders to farmers. This

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is a new risk to farmers and could be devastating to the highly leveraged farm operator. The impact of this increased risk needs to be researched. The next time interest rates rise rapidly, it may be farmers rather than bankers who sustain the losses.

The Lins-Duncan paper focuses on the more aggregate impacts of inflation on agriculture. I laud them for their attempt to do more than repeat what others have said and what we all know. However, I have serious reservations about their ability to draw conclusions about the relative impact of inflation on various commodities from the correlation data presented. I would expect a high correlation between change in dairy prices and the consumer price index; but I do not see how that means that dairy farmers fared better than a crop farmer with a more variable price and, thus, a lower correlation. I could imagine the dairy industry following the consumer price index (CPI) lagged three steps behind but changing in the same direction as the CPI and being much more seriously disadvantaged than a corn farmer whose income varied greatly but varied on the up side as well as on the down side. The high price bonanza experienced by grain farmers in the 1970s never hit the dairy industry. Low correlation could occur because the price increased more rapidly, rather than less rapidly, than the CPI.

Lins and Duncan argue that inflation does not lead to higher real land prices because of the negative impact of inflation on cash flows. However, later in the paper they argue that the "buy now before the price goes higher" strategy leads to greater purchases and, thus, higher debt; and that ownership of farm assets has been desirable because of favorable growth in real values. Both of these latter factors lead to an increased demand for farm resources, particularly land, and likely at least offset any reduced demand caused by the cash-flow problems of small and beginning farmers, leaving unaltered the high correspondence between land values and cash returns to land observed by Melichar (1980).

In their concluding paragraph, Lins and Duncan raise the specter of declining inflation rates. I personally doubt that inflation will get below the 10% range for very long in the next several years. However, it would be useful to assess the real risk position of farmers should inflation rates decline substantially rather than remain at relative high rates or increase.

Klinefelter, Pensen, and Fraser (KPF) start out by trying to define inflation. Although everyone may not agree with their definitions, the identification of "steady-pace" versus "fits-and-starts" inflation is useful. Most economists assume steady-pace inflation, but it is the fits-and-starts variety that the United States appears to be experiencing.

The authors clearly portray the shift of interest rate risk from lender to farmer with increased use of variable rate mortgages. But they do not even raise the question of whether or not that is the appropriate move for all lenders. Presumably there should be some profit connected with the assumption of interest rate risk. Financial institutions may be better able to manage that risk than farmers. If so, it may be profitable, as well as a service to agriculture, for some lenders to continue to offer a fixed rate mortgage with an interest rate risk premium.

KPF also raise the question as to whether the Farm Credit System and FmHA have the capacity to handle larger market shares. However, they do not ask the potentially more important question of whether or not increasing the market shares of these lenders is good for agriculture. The Farm Credit System has done and continues to do an outstanding job. But, can financial market efficiency really be maintained when the only competition the Farm Credit System has is the U.S. government?

Finally, it is true that the loan volume of government lending agencies (FmHA, CCC, SBA) has skyrocketed recently. However, I would contend that the primary cause is drought, export variability, and cyclical price movements rather than inflation. Economic Emergency loans could result from changes in monetary policies and interest rates; but, so far, with the exception of one small area of the country (Melichar), I doubt that inflation-induced monetary and interest rate changes triggered many of the loans.

From a longer-run perspective, inflation could reduce the effectiveness of FmHA in its ability to serve beginning and small farmers. Since the loan limits and other regulations under which FmHA works, are set by Congress and require an act of Congress to change, it may be difficult to keep FmHA loan policies current. More general legislation with greater administrative flexibility or an inflation indexed loan policy may be required.

References

LaDue, E. L. *Coping with the High Cost of Money*. Agr. Econ. Staff Pap. 80-10, Cornell University, 1980.

LaDue, E. L., and G. L. Casler. *Major Capital Investment Computer Program, Newplan Program 50*. Agr. Econ. Res. Bull. 76-2, Cornell University, 1976.

Melichar, Emanuel. "Rural Banking Condition in the First Half of 1980." Mimeographed. Washington, D.C.: Board of Governors of the Federal Reserve System, 1980.

The Impact of Landownership Factors on Soil Conservation

Linda K. Lee

Although soil erosion has been a recognized problem in the United States since the 1930s, recent soil losses have generated additional concern. This concern has been prompted by reports that soil erosion losses are increasing, thus intensifying air and water pollution problems and reducing the productivity potential of cropland. These reports accompany evidence that suggests further productivity increases from fertilizers, seed technologies, energy, and pesticides are uncertain (Crosson). These productivity trends, coupled with irreversible losses of agricultural land to urban and other uses and the possibility of increased demands for U.S. agricultural products, make the issue of conserving soil quality increasingly important.

In response to these concerns, the Soil and Water Resources Conservation Act of 1977 (P.L. 95-192) requires a continuing appraisal of the soil and water resources of the nation and analyses of the effectiveness of ongoing conservation programs. A 1977 General Accounting Office report to Congress concluded, however, that effective conservation policies may require identifying and seeking out landowners whose lands have critical erosion problems. Hypotheses about the impact of landownership characteristics such as tenure, income, and owner attitudes on soil conservation have been investigated in studies since the 1940s. Events of the 1970s have renewed interest in these hypotheses and have suggested new ones. The attention focused on the changing structure of agriculture has led to the hypothesis that a larger, more corporate agricultural structure will have unfavorable consequences for soil conservation. The objectives of this paper are, first, to examine different organizational structures to determine if there are differences in average erosion rates among them, and second, to reexamine traditional hypotheses about landownership and soil erosion from a broader perspective than previous studies. If significant differences can be identified among landownership groups, this information could be used to develop and implement more effective conservation policies.

Factors Affecting Soil Erosion

Soil management decisions at the farm level have been analyzed in the context of maximizing expected net income over a planning horizon. The rational individual calculates the income effects of a proposed conservation program over time and compares these effects to his or her expected income over time without conservation measures. Within this framework, individuals sharing similar erosion problems may reach different conservation investment decisions depending on individual time preference or discount rates and the length of their planning horizon. A lower discount rate and a longer planning horizon are thought to encourage conservation decisions by increasing the present value of expected net revenues and by allowing sufficient time to recoup conservation investments. Recent research has emphasized the importance of low discount rates and very long planning horizons in conservation management decisions (Seitz, et al.).

However, numerous economic variables as well as personal characteristics of the owner can affect the individual's choice of a discount rate and planning horizon. Individuals with low current incomes and inability to obtain

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capital for conservation investments may not be willing or able to forego income to maximize expected net returns over a longer time period. Similarly, individuals in an uncertain economic situation will be inclined to use short planning horizons because they are unable to predict future costs and prices. It also is possible that older farmers with no heirs operate under shorter planning horizons than younger ones.

Institutional factors can affect the choice of discount rate and planning horizons as well. Lack of knowledge or nonacceptance of conservation principles can lead to unfavorable conservation decisions even where there are economically favorable alternatives. Insecurity of tenure, particular leasing arrangments, absentee ownership, small operating units, high property taxes and a lack of credit facilities have all been hypothesized to be further institutional obstacles to conservation.

Recently, it has been hypothesized that changes in the ownership and control of agricultural land will have important repercussions for soil conservation. A larger, more corporate agriculture, it has been suggested, will lack a conservation ethic and will choose a planning horizon and discount rate designed to maximize current income at the expense of future soil quality (Bible).

Researchers have previously examined many of these hypotheses through studies in small, relatively homogenous areas with similar soils, climate, and topography. By minimizing changes in physical characteristics, management and ownership differences, if they exist, are identified more readily. Both economic and institutional factors were found to influence soil conservation decisions. Higher incomes were found to be associated with higher degrees of soil conservation in areas of the Midwest (Anderson, McNall, and Inman; Heady and Allen). Tenure problems and owner resistance to conservation were found to be prevalent on high erosion farms in a series of studies conducted in Western Iowa since 1947 (Frey, Held and Timmons, Blase and Timmons, Hauser). Leasing arrangements, in particular, were examined by researchers; conservation practices under crop-share leases were found to reduce landlord's income (Jensen, Heady, and Bauman). However, because of the relatively small geographical areas studied, it is sometimes difficult to determine how representative these studies may be. Also, a disproportionate number of these studies have been conducted in only one region, the Corn Belt.

In the following sections of this paper, the influence of the organizational structure of landownership units on soil erosion will be examined on a regional and national basis. In addition, the economic and institutional hypotheses about landownership and conservation explored in earlier studies will be reexamined from a regional perspective.

Data

Data for this analysis were obtained from a merger of the 1977 National Resource Inventories (NRI) conducted by the U.S. Soil Conservation Service (SCS) and the 1978 Landownership Survey undertaken by the Natural Resource Economics Division (NRED), Economics, Statistics, and Cooperatives Service (ESCS), U.S. Department of Agriculture (USDA) (Lewis). The SCS/NRI provided basic data reliable at the state level on land use, land quality, potential cropland, and erosion. The survey was a two-stage sample of 70,000 primary sampling units (PSU) of generally 160 acres. Within each PSU, three randomly selected points were inventoried. The SCS provided NRED the name and address of the owner of the first point in each sample PSU. Of the 70,000 points, names and addresses for private landowners were available for 52,000 points and slightly more than 37,000 completed landownership questionnaires were returned after follow-up procedures. For these 37,000 responses, additional land use information from the SCS/NRI was available and utilized in this analysis.

Our initial analysis focused on key landownership variables hypothesized to influence soil erosion, including type of organizational structure, income, and tenure characteristics. As income and other landownership data were not available for the corporations in our sample, one model was formulated to test for differences in mean erosion rates on land owned by different organizational units, and another model was developed to analyze erosion differences among different income and tenure groups. Analyses at the national and farm production region levels were conducted, allowing a broader examination of earlier findings. However, many possibly relevant variables and interactions among variables were omitted from this analysis. A more comprehensive analysis is planned to look at additional rela-

tionships between landownership variables and soil erosion.

Rainfall erosion data for this analysis were estimated from the Universal Soil Loss Equation (Wischmeier and Smith). It is difficult to separate the influence of management and physical factors on erosion from the Universal Soil Loss Equation data as management practices are a reaction to a natural environment. Nevertheless, in an attempt to determine the relative importance of management and physical factors in erosion differences, means for management and physical factors within the Universal Soil Loss Equation were analyzed for ownership categories. Distributions of land with conservation measures of minimum tillage or residue practices in effect were examined as a management indicator, and prime farmland and erosion-prone land (subclass e) distributions were evaluated as a measure of physical factors.

Soil Erosion Rates and Organizational Structure

Dummy variables were used in a regression model to test for differences in mean erosion rates on cultivated cropland acreage owned by different organizational units (table 1). The model was weighted by the expanded acreage estimates associated with each observation to account for probability of selection and nonresponse in the survey data. *F*-statistics were used to test the hypothesis that no difference between mean rates of erosion exists on the acreage owned by these different types of landowners. Individual coefficients were examined with *t*-tests. Because nonfamily corporations were the excluded category in this analysis, a coefficient for a given category represents the difference between the mean rate of erosion for that category and nonfamily corporations.

The results of the structure analysis indicate that nationally there are no significant differences in mean soil losses between different types of ownership groups. Since the value of the *F*-statistic was below the critical *F*-value at the .05 level, we could not reject the hypothesis that mean soil losses between groups are equal. This conclusion applied to a majority of the farm production regions tested as well. However, for four of the ten regions in the U.S., *F*-values exceeded the critical value, indicating differences in mean rates of erosion between groups did exist. Significantly, in none of these regions were these differences the result of higher average rates of erosion by nonfamily corporations. In the Northeast, Mountain, and Lake regions, the data indicate

Table 1. Erosion on Cultivated Cropland by Type of Landownership Organization

Organizational Structure[a]	National	Northeast	Lake	Southeast	Mountain
	(tons/acre/year)				
Nonfamily corporation[b]	4.98 (9,242)[c]	4.53 (364)	3.29 (471)	5.14 (748)	1.39 (1,385)
Sole proprietor	.03[d] (147,548)	1.47 3,936)	−.74 (15,933)	1.09 (7,499)	.21 (10,777)
Family ownership	.32 (144,956)	.89 (6,596)	−.50 (20,796)	6.36*[e] (3,227)	.18 (11,787)
Partnership with family members	−.24 (40,111)	8.58* (1,210)	−1.02 (2,543)	2.87 (1,354)	1.60* (3,395)
Partnership with nonfamily members	−.34 (5,129)	−.89 (167)	6.50* (144)	−1.42 (290)	.63 (628)
Family corporation	−.51 (15,469)	7.62* (281)	−.58 (869)	.28 (201)	1.62* (3,541)
Other (includes no pluralities & estates)	−.13 (14,001)	1.66 (231)	−2.17 (667)	.62 (386)	1.01 (851)
F	.79	5.69	2.57	3.82	4.24
Degrees of freedom	11,263	666	1,282	490	833

Note: R^2 statistics for this analysis were .1 or less.
[a] Determined by plurality of acres owned.
[b] Intercept.
[c] Numbers in parentheses are cultivated cropland acreage estimates for each category in thousands.
[d] Total soil loss for nonintercept categories can be calculated by adding soil loss from the nonfamily corporation categories.
[e] Asterisk denotes significance at the .05 level.

that most of the reported differences in erosion rates among types of landowners probably can be attributed to physical rather than management factors. Landownership categories experiencing more erosion had higher percentages of land with conservation practices in effect, but also included considerably higher percentages of erosion-prone land.

The situation in the Southeast region appeared to be somewhat different. In this region family ownerships averaged 6.36 more tons/acre of soil loss annually than did nonfamily corporations. While distributions of physical factors appeared to be important, management practices also differed between the two groups. Almost 57% of land owned by nonfamily corporations was operated using minimum tillage or residue practices. Only 36.4% of land owned by families had these practices in effect. The data also indicated that cultivated cropland owned by families in the Southeast is apparently more susceptible to erosion than land owned by nonfamily corporations. While 45% of corporately owned cultivated cropland had a designated erosion hazard, 54% of such family-owned land had this classification.

Several explanations for the difference are possible. First, crops grown may differ between groups. Corporate influence in vegetable production is strong in this region, so erosion differences may reflect more erosive crops, such as tobacco or peanuts, grown by family farmers. It is also possible that owner attitudes toward conservation differ between corporations and family cropland owners in this region. Another possible explanation is that family landowners in the Southeast are smaller, less affluent, and have more problems obtaining capital for conservation investments than their corporate counterparts. These factors would result in shorter planning horizons and higher discount rates for conservation investments by family groups. While income data are not available for the corporations in our sample, income effects will be tested on data for noncorporate landowners in the following section.

Erosion Differences among Noncorporate Landowners

A second weighted regression model with dummy variables was formulated to examine mean soil erosion differences on cultivated cropland among income and tenure variables found to be important in previous studies. Leasing information was not available in sufficient detail to be included. A portion of this analysis, differences in mean erosion rates among income categories for full-owner-operators, is presented in table 2. F-statistics were used to test the hypothesis that mean rates of erosion on cultivated cropland owned by different income groups are equal, while t-tests were used to examine individual coefficients. As the income category of $0–$2,999 was the excluded category in this analysis, each coefficient represents the difference between the mean soil loss for that category and the low income excluded category.

The results of our analyses do not indicate that significant differences in soil erosion rates exist between tenure groups at the national level or within most regions. Significant differences between tenure group erosion means were found in two regions, but only in the Northeast region were average erosion rates on cultivated cropland owned by full-landlords higher than erosion rates for full-owner operators. Similarly, mean levels of erosion on cultivated cropland did not differ significantly among net farm income categories nationally and for most regions. Only within the Southern Plains region were lower mean levels of erosion associated with higher net farm income categories.

Instead, the relationship between net farm income and mean levels of erosion appeared to depend on the tenure category of the landowner. For full owner-operators, those who operate only land that they own, higher income levels were associated with lower rates of erosion, nationally, and within five out of ten regions in the United States. Nationally, mean levels of erosion for landowners reporting net farm incomes between $3,000–$9,999, $10,000–$19,999, and $20,000–$49,999 were 1.34, 1.49, and 2.31 tons/acre less, respectively, than lower farm income landowners reporting $0–$2,999 as annual income. Net farm income greater than $50,000 did not appear to result in significantly lower erosion rates. However, the acreage represented by this group is relatively small and therefore subject to more sample error. The Northeast, Corn Belt, Delta, Southern Plains, and Mountain regions displayed a similar trend to varying degrees. In the Corn Belt, for example, landowners with net farm incomes of $20,000–$49,999 averaged 9.4 tons/acre less erosion on

Table 2. Rates of Erosion on Cultivated Cropland by Net Farm Income, Full-Owner-Operators

Net Farm Income	National	Northeast	Corn Belt	Delta	Mountain	Southern Plains
	(tons/acre/year)					
\$0–\$2,999[a]	5.62 (8,189)[b]	1.69 (379)	13.78 (1,476)	14.29 (103)	.45 (364)	6.19 (549)
Less than \$ 0	.07[c] (12,434)	7.80**[d] (219)	−2.83 (2,354)	12.17*[e] (212)	2.07** (2,137)	−.41 (1,258)
\$3,000–\$9,999	−1.34* (15,229)	2.36 (661)	−6.53** (3,413)	8.65 (134)	1.45* (1,554)	3.16* (668)
\$10,000–\$19,999	−1.49* (8,591)	1.35 (365)	−6.57** (2,709)	−4.89 (62)	1.43 (610)	−4.34** (441)
\$20,000–\$49,999	−2.31** (6,902)	4.30 (191)	−9.40** (1,925)	−8.84 (212)	1.01 (784)	−3.25* (932)
\$50,000 and over	1.35 (2,600)	.02 (95)	1.98 (647)	−9.02 (414)	.69 (199)	−3.31 (354)
F	3.41	2.65	3.82	2.97	1.98*	2.29
Degrees of freedom	1,609	90	399	46	155	90

Note: R^2 statistics for this analysis were .27 and less.
[a] Intercept.
[b] Numbers in parentheses are cultivated cropland acreage estimates in thousands.
[c] Total soil loss for nonintercept categories can be obtained by adding soil loss from the net farm income category of \$0–\$2,999.
[d] Asterisks denote significance at the .05 level.
[e] Asterisk denotes significance at the .01 level.

cultivated cropland than did low income owners of \$0–\$2,999.

In the Northeast, Delta, and Mountain regions, full-owner operators who experienced net losses had the highest reported erosion rates. Since the excluded category in this analysis was net farm income of \$0–\$2,999, t-values for coefficients in these regions may not be significant, although differences between erosion rates for net farm losses and other categories are pronounced. For example, in the Delta, landowners with net losses averaged 26.4 tons/acre soil loss compared to 5.3 tons/acre by the highest income landowners in the region.

The association between net farm income and erosion was confined to full-owner operators. Off-farm income and total income variables were also tested for mean erosion differences within tenure groups and for all data, but no significant trends were detected.

The relationship between higher incomes and lower rates of erosion for owner-operators appears to result from a combination of less erosive land and more conservation practices. Nationally, only 40% of cultivated cropland owned by the most affluent landowners is classified as having an erosion hazard, while 59% of cultivated cropland owned by the lowest income group is labeled erosion prone. This trend can be found in most of the regions of the United States. In terms of management, 60% of cultivated cropland owned by landowners with net farm income greater than \$50,000 had minimum tillage or residue practices in effect, while 47% of such land owned by those with net farm incomes of less than \$3,000 had these practices at the national level.

In the five regions for which significant differences in mean erosion rates between farm income categories occurred, distributions of physical and management characteristics reflected the national trend. However, in two regions with major erosion problems, Appalachia and the Southeast, mean rates of erosion for full-owner operators did not differ among income groups. Furthermore, examination of land quality and management data for these regions did not reveal a well-defined pattern. One possible explanation is that for some of the crops important to these regions, such as tobacco, recommended tillage practices are erosive and higher incomes alone may not result in improved management practices. Owner attitudes toward conservation may differ in these regions as well.

Conclusions

Further research is needed to address the issue of landownership impacts on soil conservation. As noted earlier, this analysis is a

partial one. Additional analysis is underway to provide a more comprehensive analysis of landownership factors, including age and education, that might affect soil conservation decisions. Also, our analysis is based on cross-section data from 1977–78. However, many of the relevant questions about landownership and conservation refer to dynamics—what are the implications of a changing structure of agriculture for soil conservation? It is hoped this analysis will provide a first step toward subsequent long-run research on these questions.

With these qualifications in mind, this analysis does provide some insight into landownership impacts on soil conservation. First, these data indicate that corporations do not have higher average rates of erosion than other types of landowners. Nationally, and within most regions, there do not appear to be significant differences in mean rates of erosion on cropland owned by different types of organizational units. Furthermore, with the possible exception of the Southeast, no significant differences in mean rates of erosion between types of landowners were found to be principally due to management.

For noncorporate landowners, the results of this analysis are generally consistent with previous studies with respect to net farm income, although no significant differences between rates of erosion and tenure groups were found. However, net farm income was found to exert more influence within the full owner-operator tenure group than other tenure categories. It is possible that if additional information on the type and length of lease were tied to the erosion data, erosion differences among landlords would be evident. However, as a group, landlords do not automatically appear to have more soil losses than those who operate their own land or those who combine landlord, tenant, and owner-operator functions. Full landlords and part-owners do appear to have a different relationship between net farm income and erosion than full owner-operators. Thus, policies designed to encourage conservation through income incentives may not have similar effects in all tenure groups. Currently, our research indicates only 25% of cropland in the United States is owned by full-owner operators. Another 30% is owned by full-landlords, and the remainder is owned by those who are a combination of landlords, tenants, and owner-operators.

Finally, this analysis indicates regional differences do exist, at least with respect to income and tenure variables. Of five regions in the United States experiencing average rates of erosion on cultivated cropland above 5 tons/acre, income and tenure variables provided some explanation of erosion differences in the Northeast, Corn Belt, and Delta. For the Appalachian and Southeastern regions, however, another model may be more appropriate. The characteristics of the types of crops grown in these regions as well as owner attitudes toward conservation may provide some explanations.

References

Anderson, H. O., P. E. McNall, and B. T. Inman. *Progress in Application of Soil Conserving Practices, Southwestern Wisconsin*. USDA ARS 42–43, Apr. 1957.

Bible, Alan. "Impact of Corporation Farming on Small Business." *Farm Workers in Rural America, 1971–1972, Part 3*. U.S. Senate Committee on Labor and Public Welfare, Hearing before the Subcommittee on Migratory Labor, 92nd Cong., Washington, D.C., 1972.

Blase, Melvin G., and John F. Timmons. *Soil Erosion Control in Western Iowa: Progress and Problems*. Iowa State University Agr. Exp. Sta. Res. Bull. 498, 1961.

Crosson, Pierre. "Demands for Food and Fiber: Implications for Land Use in the United States." *Land Use: Tough Choices in Today's World*, pp. 49–61. Ankeny, Iowa: Soil Conservation Society of America, 1977.

Frey, John C. *Some Obstacles to Soil Erosion Control in Western Iowa*. Iowa State University Agr. Exp. Sta. Res. Bull. 391, Oct. 1952.

Hauser, Wade Rodwell, III. "Soil Erosion Control in Western Iowa." M.S. thesis, Iowa State University, 1976.

Heady, Earl O., and Carl W. Allen. *Returns from and Capital Required for Soil Conservation Farming Systems*. Iowa State University Agr. Exp. Sta. Res. Bull. 381, May 1951.

Held, R. Burneld, and John F. Timmons. *Soil Erosion Control in Process in Western Iowa*. Iowa State University Agr. Exp. Sta. Res. Bull. 460, Aug. 1958.

Jensen, Harold R., Earl O. Heady, and Ross V. Bauman. *Costs, Returns, and Capital Requirements for Soil-Conserving Farming on Rented Farms in Western Iowa*. Iowa State University Agr. Exp. Sta. Res. Bull. 423, Mar. 1955.

Lewis, James A. *Landownership in the United States, 1978*. Washington, D.C.: U.S. Department of Agriculture ESCS Agr. Info. Bull. 435, Apr. 1980.

Seitz, Wesley D., et al. "Economic Impacts of Soil Erosion Control ." *Land Econ.* 55(1979):28–42.

Conversion of Noncropland to Cropland: The Prospects, Alternatives, and Implications

Robert N. Shulstad and Ralph D. May

A major conclusion of researchers in universities, government, and private research institutes is that the United States has adequate agricultural resources to meet and exceed any projected increases in the domestic demand for food and fiber and to provide these goods at reasonable prices. Most researchers would also agree that domestic demand could be accommodated without the conversion of noncropland to cropland and without significant environmental damage. However, the responsibilities of the U.S. agricultural machine have been broadened to include not only U.S. consumers but also the willing and able buyers of the rest of the world. Most of the world export market is currently supplied by the United States (Frey and Otte, Heady and Timmons).

Ericksen and Johnson present projections prepared by the Economics, Statistics, and Cooperative Service (ESCS) analysts which predict an expanding market for U.S. agricultural products. Their supply and demand forecasts indicate that the 1980s generally will be a period of intermittent tight supply which will test the ability of the United States to respond to an increase in demand for food and feed grains. The full production potential of U.S. agriculture will be needed to meet the anticipated level of demand.

The potential for increased production depends on the ability to increase yields or to increase the cropland base. Though technological innovations, such as improved varieties, planting rates, fertilizers, and pesticides, have combined to substitute for land to increase yields during much of the twentieth century, continued yield growth is questionable. Yield increases at rates comparable to those of the 1950s and 1960s are not realistic, especially in the face of increased fertilizer, chemical, and irrigation costs, decreasing budgets to support basic research in plant breeding, and more stringent regulations to control the externalities of agricultural production.

Production records through 1978 generally support the hypothesis that growth in yields has plateaued or actually decreased (Crosson). However, Heady recently argued that "when the record yields of 1979 are included, quantitative proof does not yet exist to indicate that U.S. crop yields generally are now plateauing" (Heady, p. 23). If they are not, the question is whether growth in yields will be adequate to compensate for growth in demand.

Should yields continue to increase at the 1972–78 rate, Crosson estimates an additional 70 million acres above 1977's 331.6 million acres will be required to meet the U.S. Department of Agriculture (USDA) projected demand for the year 2000 (Crosson, p. 102). This substantial increase in the cropland base must come from lands that have a potential for conversion to cropland rather than cropland held out of production under government programs (Ericksen and Johnson). Though set aside and diverted cropland amounted to 62 million acres in 1972, no land was set aside or diverted from 1974 through 1977. The upgrading of present cropland by drainage, landforming, and irrigation may also provide for increases in production.

Potential for Expansion

The potential of the United States to expand its cropland base has been the subject of numerous studies (Amos and Timmons; Cotner, Krause, Skold; Davis; Dideriksen, Hildebaugh, and Schmude; Frey and Otte; Lee; Shulstad, May, Herrington). Most re-

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searchers have relied on the 1967 National Inventory of Soil and Water Conservation Needs (CNI), the *1975 Potential Cropland Study*, or the more recent National Resource Inventory (NRI) to provide base data for their estimates (Cotner, Krause, Skold; Dideriksen, Hildebaugh, Schmude; Frey and Otte; Lee.) The techniques used in these studies are similar—SCS district conservationists conferred with the local county agent, the Agricultural Stabilization and Conservation Service county manager, and the local Farmers Home Administration officer in order to rate each survey point on its potential for conversion.

The Soil Conservation Service *1975 Potential Cropland Study* identified 78 million acres of noncropland as having high potential for cropland development and an additional 33 million as having medium potential under 1974 agricultural product-price relationships. Thirty-five million acres of the high potential land was believed to have no limitations to development (Dideriksen, Hildebaugh, Skold). The preliminary results of the NRI indicate that nearly 36 million acres of pasture, range, forest, and other lands has high potential and 91 million acres has medium potential for conversion to cropland under the less favorable 1976 prices and production costs (Brewer and Boxley). It is further estimated that only 2.2 million acres could be converted quickly to crop production without major outlay for soil preparation or water facilities (Ericksen and Johnson).

Lee, in *A Perspective on Cropland Availability*, expands on the Dideriksen, Hildebaugh, Schmude *1975 Potential Cropland Study* to provide detailed accounting of convertible cropland by region and the associated limitations to conversion. Major difficulties include erosion hazards, clearing and/or drainage, limited water or fertility, and ownership problems. Lee and others who have published reports on the subject call for additional research into the cost, both public and private, of converting noncropland to cropland and more evaluation of the potential for conversion at various stages in the product-price relationship (Brewer and Boxley, Frey and Otte).

The General Accounting Office in a report to Congress criticized the USDA potential cropland study for failing to consider the current agricultural use of potential cropland and owner preferences. The General Accounting Office recommended that potential cropland estimates be developed in which consideration is given to current land use, production tradeoffs, development problems and costs, and other economic values such as changes in the relationship of production and development costs to commodity prices.

Regional Potential

Regional efforts to quantify the economic feasibility of converting noncropland to cropland are exemplified by studies conducted at Iowa State University and the University of Arkansas. The studies by Amos and Timmons in Iowa and Shulstad, May, and Herrington in Arkansas are part of a larger effort by Resources for the Future to project the potential for acreage expansion, its implication for soybean production, and the possible environmental consequences.

The Iowa and Arkansas studies evaluated the present land use and the opportunity costs associated with conversion, and enumerated the costs of the conversion process including clearing, drainage, land preparation, and maintenance. The gross returns to converted land were compared with the full private costs associated with that land—i.e., the conversion costs, the operation and maintenance costs, and the opportunity costs—to evaluate the feasibility of conversion.

In both studies a land type matrix was constructed whereby land is classified by soil productivity class and land use. Productivity classes are aggregations of soil-mapping units into groups that are homogenous in terms of yield, production costs, and management techniques.

The Iowa team used two sets of land-use data, the 1967 Conservation Needs Inventory and the 1977 National Erosion Inventory. Those sources could not easily provide data for the Mississippi Delta which is made up of subregions of several states. Therefore, a sample of seven counties was selected within Arkansas, which is proportionally representative of the Delta soils. Land-use data for these counties were obtained from the Resource Information Data System (RIDS) data bank. RIDS is a joint effort of the Soil Conservation Service and the Economic, Statistics, and Cooperatives Service to identify land use for the center of each square kilometer by field survey. Information is retrieved by soil-mapping units and can be aggregated into pro-

ductivity classes based on the characteristics believed most significant by the researcher.

Conversion costs were obtained from field surveys of commercial land clearers and drainage experts as well as farmers who had recent conversion experience; annual production and maintenance costs were those representative of the study areas. The Iowa study used the USDA production budgets and the Arkansas study used the 1978 Arkansas crop budgets.

Each study considered alternative scenarios to determine the potential for expansion on the extensive margin of production. Product prices were those used in the USDA Grain-Oilseeds and Livestock Model (GOL) and reflected 1985 baseline conditions and 1985 high demand conditions. Under baseline conditions, world grain trade prices in real terms are assumed to average closer to the low levels of the 1969/70–1971/72 base period than the high levels of the 1972/73–1974/75 period. Under high demand conditions, real grain prices would be substantially higher than those of the base 1969–72 period but still below the levels of 1972–75.

The scenarios examined in both studies involved 1985 baseline and high demand prices; normal regional yields and yields representing those obtained by the top 10% of managers; normal production costs and variable production costs increased by 33%; three alternative rates of discount; a twenty-year planning horizon; and alternative crop rotations.

Comparison of the Iowa and Arkansas findings shows the economic feasibility of the conversion process to be much more sensitive to changes in price and cost levels in Iowa than in the Mississippi Delta region.

Within the ranges of crop prices, input prices, conversion costs, and yields assumed, the elasticity of supply with respect to crop prices ranged from 6 to 13 in the Iowa study and from 0 to 3.4 in the Mississippi Delta Study. The elasticity of supply with respect to variable production costs ranged from −4 to −6 in Iowa and from 0 to −2.14 in the Delta.

Under the most optimistic assumptions examined, and under all scenarios assuming high management, all the remaining privately owned woodland and pastureland within the Mississippi Delta region that is not frequently flooded or too steep is economically feasible for conversion. This land amounts to 2.6 million of the 25.36 million acres within the region. Under the most unfavorable assumption the potential for conversion is reduced to 1.38 million acres. The potential for conversion in Iowa ranges from a high of 3.86 million acres to 50 thousand acres (Amos and Timmons).

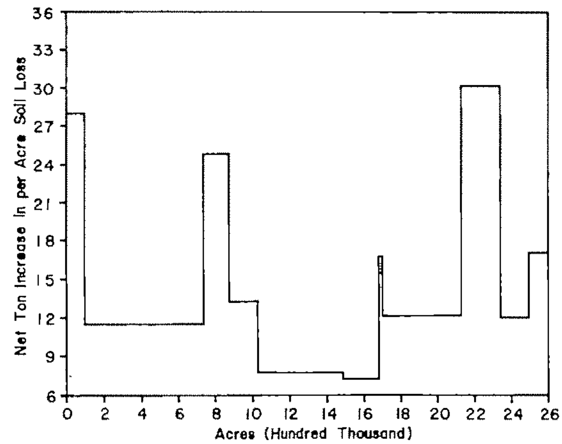
Both Iowa and the Mississippi Delta region have potential for significant increases in the cropland base—11% and 10%, respectively. Neither region, however, is representative of the potential 37% reported at the national level (Brewer and Boxley). Moreover, the results of regional studies must be examined in the context of the nationwide potential for increased production. Major increases in one region could easily be offset by decreases in other regions.

Environmental Effects of Land Conversion

The conversion of noncropland to cropland is analyzed through the comparison of private costs and returns. External costs and benefits are undoubtedly generated in the conversion process, and environmental regulations are now attempting to force the consideration of these costs and benefits by the farmer. An estimate of the external cost of the conversion process was developed in the form of increased soil erosion in tons per acre per year.

Several serious environment consequences result from additional land conversion. One is an increase in soil erosion. Woodland and pastureland are land uses which minimize soil loss. The conversion of woodland and pastureland to cropland will increase soil loss dramatically on those acres. The extent of the increase in soil loss depends on the particular soil group and the crop rotation selected.

Variation in the cost, price, and yield assumptions leads to variation in the crop rotations determined to be optimal for each soil productivity group and has major implications for the resulting erosion. Figure 1 is a plot of the per acre increases in soil loss caused by conversion of woodland and pastureland in the Mississippi Delta region under conditions of 1985 baseline prices, high yield management, normal production costs, and a discount rate of 10% (Shulstad, May, and Herrington). Per acre soil loss is plotted against the acreage of soil in each soil group. In all scenarios the first soil group to be converted consists of soils that have moderate permeability, loamy surface texture, and 1% to 3% or gently undulating slope. These soils provide the greatest private rate of return to conversion but also have the highest soil loss per acre after conversion.



Note: Figure shows per acre increases in soil loss resulting from conversion of woodland and pastureland in the Mississippi Delta region under conditions of 1985 baseline prices, high yield management, normal production costs, and a discount rate of 10%.

Figure 1. Soil loss from converted woodland and pastureland

Under most alternative scenarios, the soils having slow permeability, loamy surface texture, and 1% to 3% or gently undulating slope have the lowest potential for economical conversion. These soils are also very erosive. The remaining soil groups have lower per acre soil losses after conversion.

If land is converted in descending order of its rate of return, average soil loss will not be related directly to the quantity of land converted within the Mississippi Delta region.

Both the Mississippi Delta and Iowa studies indicate conversion of noncropland to cropland can be extremely detrimental to environmental quality if effective soil erosion control measures are not used.

Within the Mississippi Delta region, the weighted average increase in per acre soil loss ranges from 8.47 tons per acre per year with 2.4 million acres converted to 14.06 tons per acre per year with 2.6 million acres converted. Average soil loss for converted acreage in Iowa ranges from 15.4 to 98 tons per acre per year.

Amos and Timmons limited soil loss to no more than 5 tons per acre per year and introduced additional agricultural practices for soil loss control. In a controlled situation, the average percentage decrease in potential cropland in Iowa is 44%, ranging from 2.1% to 68.3%. Gross soil loss is reduced 97.5%, ranging from 95.6% to 98.6%, and net income decreased about 46%, ranging from 6.4% to 89.1% (p. 143). The average soil loss is generally less than 2 tons/acre/year.

Seitz and his associates at the University of Illinois found it unreasonable for farmers to restrict their production methods in order to decrease soil erosion if their planning horizon is of a normal twenty- to thirty-year length. This being the case, federal or state programs will be required to change the incentive structure faced by farmers. However, the relationship between erosion and soil productivity remains ill-defined. Research is underway to quantify the relationship. An extensive review of this research is provided in a recent SEA white paper.

Another adverse environmental effect of land conversion is an increase in chemical and fertilizer runoff. Table 1 shows the total increase in fertilizer and pesticides applied per year to converted land in the Mississippi Delta. Concern for excessive pesticide con-

Table 1. Total Increase in Applied Materials on Converted Land Per Year: All Crops

Applied Material	Application Rate per Acre	Total Quantities Applied
	2,592,299 Converted Acres in Mississippi Delta Region	
Nitrogen[a]	93,772,454 lbs.	(46,886 tons)
Phosphate	44,165,920 lbs.	(22,083 tons)
Potash	87,623,533 lbs.	(43,812 tons)
Treflan	1,613,167 qts.	(403,292 gal.)
Cotoran	758,473 lbs.	(379 tons)
Cotoran + MSMA	1,198,091 qts.	(299,523 gal.)
Dinoseb	1,226,290 lbs.	(613 tons)
	365,008 qts.	(91,252 gal.)
Basagran	174,276 qts.	(43,569 gal.)
2,4-DB	463,754 lbs.	(232 tons)
Karmexdl + MSMS ×2	214,179 qts.	(53,545 gal.)
Tox + MP	1,960,077 gal.	(1,960,077 gal.)
EPN + MP	84,575 gal.	(84,575 gal.)
Defoliant	1,523,381 pints	(190,443 gal.)

[a] All estimates are based on an average rotation year.

centration in Delta rivers is increasing and state pollution control agencies are attempting to monitor concentration levels. Enforcement of section 208 of PL 92-500 remains tied to voluntary participation, with the hope that federal funds will be available to subsidize control mechanisms.

The economic value of the environmental impacts of conversion of noncropland to cropland has not been quantified. However, institutional changes which force a restriction of soil loss or pesticide runoff will slow the conversion process.

Alternatives to Conversion

Though significant yield increases are not expected to occur at the national level, the potential remains for increased production on the intensive margin within some regions. The Mississippi Delta study examined the potential for the upgrading of present cropland through land forming as an alternative to land conversion.

Land forming is a process of cutting down high spots and filling in low spots to create a field of uniform shape and slope. The field is first surveyed to determine the areas to be cut, filled, or left alone. Tandem dirt buckets are pulled behind huge tractors to make the cuts and haul the soil to lower areas where it is dumped as smoothly as possible to create roughly the desired slope. When the dirt bucket work is finished, a land plane is pulled over the field to smooth the soil to the final grade. Because of the exacting nature of the land-forming process, many farmers prefer to hire custom land formers rather than do the work themselves. Only 0%–1% slopes and gently undulating slopes are considered for land forming.

Land forming is also performed to eliminate old, meandering sloughs and ditches that run through fields. Local soil experts estimate this filling often increases the farmable land area of a field by 10%.

The effects of slope creation and field consolidation are immense. Drainage is improved by the elimination of low spots and the creation of better slopes. Yields are improved as a result of better drainage. The acreage of farmable land is increased with the filling of old sloughs and ditches. The efficiency of time, labor, machinery, and chemicals is increased. However, land forming can be radical surgery on some soil groups, especially those having thin top soil. Some cuts may go below the top soil into the subsoil and create spots which yield poorly for a time. The lower areas and filled sloughs and ditches are spongy until the soil settles. For these reasons a period of adjustment is required before most soils reach their pre-land-forming yields. This period varies widely among soils as do the yield reductions in the years immediately following land forming. After this period yields increase over those of nonformed cropland of the same soil group.

Rice rotations are increasingly being used as a follow-up to land forming in the Mississippi Delta because rice returns higher levels of organic matter to the soil than most other crops and does not undergo the yield reductions associated with other crops.

Land forming does add an extra cost to crop production. The field must be land planed to maintain the desired slope. Most farmers prefer to make two trips over the field yearly with the land plane but time factors sometimes prevent them from doing so.

The acreage of present cropland that could be economically land formed in the Mississippi Delta region is estimated to be 12.6 million acres. The increase in soybean production which could result from land forming in the Delta region ranges from 50 million bushels or 18.5% of 1978 production to 58 million bushels or 21.5% of 1978 production depending on the scenario examined.

The increase in regional soybean production attainable through land conversion ranges from 26 million bushels or 9.8% to 71 million bushels or 26.4%.

The conversion of noncropland to cropland and the upgrading of present cropland can be conducted simultaneously. The total increase in soybean production attainable from conversion of new acres and land forming of present cropland in the Mississippi Delta region ranges from 76 million bushels or 28.3% of 1978 production to 121 million bushels or 45.0% of 1978 production. The low estimate is based on the assumption that all land forming and land conversion is done by average managers. The high estimate is based on the assumption that the conversion is done by the upper 10% of managers.

The change in soil loss after land forming was not computed. However, the forming process creates a uniform slope of smaller magnitude than the slope on nonformed land.

Thus, land forming decreases soil loss per acre.

Irrigation

Irrigation is another alternative for increasing production on the intensive margin at the regional level. A study of the potential for additional irrigation in the Mississippi Delta region currently underway at the University of Arkansas indicates that soybean output can be increased from 26% to 71% through the economically efficient application of irrigation.

The environmental consequences of irrigation in the region are not well understood, but are believed to be less severe than those associated with gaining an equal increase in production through land conversion.

The potential for productivity gains through irrigation at the national level is much less promising (Heady).

Summary and Implication

The National Agricultural Land Study estimates the United States has the potential to increase cropland acreage by 37% (Brewer and Boxley). Regional studies in Iowa and the Mississippi Delta project the potential to convert only an additional 10%, based on 1985 price levels.

The conversion of noncropland to cropland is proceeding rapidly throughout the Mississippi Delta region, time and capital restrictions being the primary limiting factors.

Increases in soybean production as great as 45% are economically attainable within the Mississippi Delta region through the simultaneous conversion of noncropland to cropland and the upgrading of present cropland through the process of land forming. Increases in the region's soybean production of up to 21.5% can be accomplished through the upgrading of present cropland alone without any environmental damage caused by increased soil erosion.

The decision to convert noncropland to cropland has been shown to be sensitive to changes in the levels of conversion costs, yields, and production costs. Thus, regional studies such as those examined here may be needed to predict accurately the rate of conversion and the implications for society.

Agricultural and environmental agency decision makers must examine closely the incentive system now influencing the individual farmer and determine its implications for regional, national, and world communities.

References

Amos, Orley Milton, Jr., and John F. Timmons. "Supply of Potential Cropland in Iowa." Report to Resources for the Future, Dep. Agr. Econ, Iowa State University, 1979.

Brewer, Michael, and Robert Boxley. "Potential Supply of Cropland." Paper presented at Resources for the Future National Conference on the Adequacy of Agricultural Land—Future Problems and Policy Alternatives, Washington, D.C., 19–20 June 1980.

Comptroller General of the United States. *Preserving America's Farmland—A Goal the Federal Government Should Support*. Washington, D.C.: United States General Accounting Office, OED-79-109, 20 Sep. 1979.

Cotner, M. L., O. Krause, and M. D. Skold. *Farmland: Will There Be Enough?* Washington, D.C.: U.S. Department of Agriculture ERS Bull. 584, May 1975.

Crosson, Pierre. "Agricultural Land Use: A Technological and Energy Perspective." *Farmland, Food and the Future*, ed. Max Schnepf, pp. 99–112. Ankeny, Ia.: Soil Conservation Society of America, 1979.

Davis, Bob. *Economic Potential for Converting Woodland and Pasture to Cropland: Lower Mississippi Valley and Southeast*. Washington, D.C.: U.S. Department of Agriculture ERS Bull. 495, Jan. 1972.

Dideriksen, Raymond I., Allen R. Hildebaugh, and Keith Schmude. *1975 Potential Cropland Study*. Washington, D.C.: U.S. Department of Agriculture SCS Statist. Bull. 578, 1977.

Ericksen, Milton H., and James D. Johnson. "Commodity Policy Issues for the 1980s." *S. J. Agr. Econ.*, no. 1 (1980), pp. 17–28.

Frey, H. Thomas, and Robert C. Otte. *Cropland for Today and Tomorrow*. Washington, D.C.: U.S. Department of Agriculture ERS Agr. Econ. Rep. 291, July 1975.

Heady, Earl O. "Technical Change and the Demand for Land." Paper presented to Resources for the Future National Conference on the Adequacy of Agricultural Land—Future Problems and Policy Alternatives, Washington, D.C., 19–20 June 1980.

Heady, Earl O., and John F. Timmons. "U.S. Needs for Food and Fiber Demands with Inherent Policy Implications." *J. Soil and Water Conserv.* 30(1975):15–22.

Lee, Linda K. *A Perspective on Cropland Availability*. Washington, D.C.: U.S. Department of Agriculture Agr. Rep. No. 406, July 1978.

Science and Education Administration, National Soil Erosion-Soil Productivity Research Planning Committee. "The Influence of Soil Erosion on the Potential Productivity of Soil-SEA Viewpoint." Paper presented to RCA Steering Committee, Washington, D.C., 18 June 1980.

Seitz, W. D., et al. *Alternative Policies for Control of Nonpoint Sources of Water Pollution from Agriculture*. University of Illinois Institute for Environmental Studies EPA-600/5-78-005, Apr. 1978.

Shulstad, Robert N., Ralph D. May, and Billy E. Herrington, Jr. "Cropland Conversion for the Mississippi Delta Region." Report to Resources for the Future, University of Arkansas Agr. Exp. Sta., Apr. 1979.

Economics of Soil Conservation from the Farmer's Perspective

Wesley D. Seitz and Earl R. Swanson

Examination of the private economics of soil conservation is particularly germane at this time of policy reassessment under the provisions of the Soil and Water Resources Conservation Act of 1977. An understanding of farmers' perceptions of their economic interests is essential in the development of policy instruments that will achieve social objectives.

We classify the evidence on the farmer's perspective into (*a*) what farmers say about soil conservation as indicated in surveys of opinion, (*b*) the record of what they are doing, and (*c*) the results of models which purport to show what farmers are, should be, or are going to do. A final section of the paper deals with modeling needs.

What Farmers Are Saying

Four recent surveys of farmer opinions provide a limited sample of farmers' perceptions relative to the soil erosion problem and the appropriate means to deal with it. Seitz et al., Hoover and Wiitala; Pollard, Sharp, and Madison; and Fisher, Boyle, Schulman, Bucuvalas conducted surveys in Illinois, Wisconsin, Nebraska, and the United States, respectively. While each of these surveys has some shortcomings, they provide a basis for understanding farmers' beliefs on soil erosion questions. They indicate, directly or indirectly, that farmers perceive the existence of a soil erosion problem and many believe they should improve soil conservation on their farms. Young farmers, new owners, and conservation-practicing farmers were the most likely to recognize the need for additional practices. Changing tillage practices and crop rotations were more popular with farmers than contouring and terracing. A joint effort between government and farmers is the approach most favored to address the soil conservation problem. Policies that allow flexibility in the means of achieving conservation are preferred by farmers.

Fisher found that 62% of farmers favored taking away farmers' benefits provided by the Department of Agriculture if farmers do not properly protect the soil and water. He adds (p. 87), "It is clear that it is not mandatory programs per se that farmers reject. They reject mandatory programs that do not provide some compensation or cost-sharing."

In summary, these opinion surveys indicate a recognition of the gap between conservation levels provided by private economic incentives and social objectives. There is a continuing need to explore how various policy instruments modify the levels of private economic incentives.

What Farmers Are Doing

Although not a perfect operational conservation goal, especially when both productivity and off-site damage are considered, we accept the soil loss tolerance (*T*-value) as a standard of performance to judge what farmers are doing. The average *T*-value on cropland, pasture, and forest land is about four tons per acre per year. The 1977 Natural Resources Inventory indicated that approximately 34% of the nonfederal cropland experienced sheet, rill, and wind erosion at rates exceeding the tolerance level (USDA., p. 8). The Comptroller General's report indicated that both cooperators and noncooperators have soil losses above *T*-values (p. 16). It is difficult to estimate national historical trends in these estimates. However, Timmons (p. 5) has estimated that erosion losses have increased in Western Iowa since the early 1970s. There is reason to believe that similar patterns characterize much of the Corn Belt and perhaps the rest of the nation

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Another form of information on farmer actions, and one which may be an important factor in changing farmer opinions is anecdotal evidence from the popular farm press. We frequently find stories of individual farmers adopting conservation practices and they have indicated, within their accounting framework, that the conservation systems have increased returns (e.g., Cole, Gogerty, Anonymous, Vogel). While their accounting systems may be suspect, they indicate the economic potential that may exist by increasing the level of soil conservation.

Modeling Farmer Decisions

Whether the results of modeling efforts can be introduced as evidence of the farmers' perspective on the economics of soil conservation depends, of course, on the degree of correspondence of the model with reality. In the limited sampling of results which follows, we find that the private economic incentives for soil conservation are weak.

Fifteen years ago Held and Clawson appraised the strength of the economic incentive for soil conservation as follows:

> In the absence of public subsidy, much proposed soil conservation has a low profit potential, some is even negative, and only comparatively little promises to be highly profitable. . . . If this general conclusion is true, then it goes far toward explaining the modest progress of past soil conservation, both in many regions and nationally, and it has great significance for the future. (p. 265)

Much of the literature Held and Clawson reviewed consisted of studies of actual farms (e.g., North Central Farm Management Research Committee). Since that time there has been a shift from the use of forage crops to the use of a wider variety of practices, with emphasis on conservation practices that do not require rotation changes. Erosion control by use of crop rotations with forage implies the adoption of livestock to make soil conservation profitable. Thus the study of actual farms, whether by budgeting or regression methods, encountered considerable difficulties in isolating the consequences of the specific practices reducing soil erosion from such factors as the variability among farmers in the efficiency of livestock production. Further, these studies could not explicitly incorporate such critical relationships as those among crop yield, depth of topsoil, and optimal level of fertilization. These, and other features, such as discounting future costs and returns, awaited the use of the more formal planning models discussed below.

One of the reasons for the shift from the statistical study of actual farms to some form of optimization modeling was the difficulty in interpreting results of analyses of actual farms due to the confounding of the effects of soil conservation with other practices. One of the simplest modeling efforts is to use the capital budgeting model with the Universal Soil Loss Equation and to examine the profitability effects of the discount rate and the planning horizon (Swanson and Harshbarger). A large number of studies using linear programming methods, often at the watershed level, have contributed to our understanding of the problem as one of profit maximization constrained by soil loss tolerance levels (for a recent example, see White and Partenheimer). In general, these studies support the weak private economic incentive hypothesis.

Control theory has been used to a limited extent. Burt has illustrated the use of control theory in analyzing the economics of soil conservation in the Palouse area of the Northwest. His analysis suggests that, when compared to rotations with lower percentages of wheat, intensive wheat production with good cultural and fertilization practices is economically justified. In another control theory application, Frohberg and Swanson solved for the optimal levels of soil erosion considering off-site damage, various discount rates, and demand scenarios. They found that, from a societal view, the soil tolerance levels in the watershed studied provided reasonably good guides for determining appropriate soil conservation levels.

The study by Young, Taylor, and Holland is an example of the use of a simulation model to analyze the long-run incentives for adoption of soil-conserving tillage systems in the Palouse. They conclude (p. 55) that if soil conservation researchers develop farming systems that save soil but which decrease yields and/or increase costs, while at the same time agricultural scientists as a whole continue making advances that increase yields in spite of topsoil depletion, economic incentives will continue for many years to favor the use of more erosive systems.

Another simulation study predicted adoption rates for minimum tillage to increase from its 1974 level of about 10% to slightly more

than 80% by the year 2010 (U.S. Senate). These rates were based, in part on the patterns of adoption of other technologies and are perhaps higher than they might have been had the economic behavior been modeled in the same level of detail as in the study by Young, Taylor, and Holland.

Modeling Needs

If we can model the farmer's soil conservation decision process more completely, we can better understand the process and communicate more effectively with decision makers. We could begin with simple farm LP models with alternative crops and practice combination budgets. To these models one could add variables and constraints or use goal-programming methods until we have identified more of the relevant features (Willis and Perlock). While such an oversimplified annual profit maximization model, with a few constraints, may miss a great deal, it may be effective in encouraging the choice of profitable soil conservation practices. But simple models are not adequate to represent the more complex choice process, so let us explore some of the additional factors of concern to the farm operator.

Long-Term Time Considerations

The topic of the farmer's perspective is on today's agenda in part because of the implications of soil loss on productivity over time, so perhaps we should start with the need to stretch the modeling period to cover the farmer's planning horizon (Frohberg; Guntermann, Lee, Narayanan, and Swanson; and Nelson and Seitz). To do so, we need to know the impact of practices on soil losses and, in turn, on yields and incomes.

Within-Season Considerations

The choice of conservation practices affects the timing of farm operations. For example, fall plowing reduces the number of field operations in the spring when time is of the essence. Contours and terraces are inconvenient with today's large machinery. Some conservation practices reduce the number of trips required for seedbed preparation. Recommended pesticide application methods requiring incorporation often result in more tillage operations than desirable for soil conservation.

Investment Decisions

The switch to a new form of tillage generally requires the purchase of new equipment. In some cases, two sets of planting and tillage equipment must be maintained. Additional financial resources may be required to purchase this equipment. Other conservation alternatives require a considerable investment (some terrace systems can approach $1,000 per acre). Recognizing the impact of the uncertain nature of farm income on this decision process would further enhance the reality of the modeling effort.

Resource Control Arrangements

The modeling effort also needs to capture the important patterns of the acquisition and control of resources. With respect to land, we not only have the more common owner-operator, and the owner-renter situations, but with the advent of the professional manager explicit recognition needs to be given to the owner-manager-renter. Further, there are part-owners who rent land from various landlords, some of whom hire professional managers. Such a farm operator is likely to need to maintain several types of tillage equipment in order to satisfy preferences of all involved and match the conditions found on the several farms. In general, the optimal level of soil conservation is likely to vary among parties in the land-control arrangements and a reconciliation of these diverse objectives is important.

Influence of Public Policy

Another element influencing the adoption of conservation practice is the public policy environment in which the firm operates (Seitz et al., Nelson and Seitz). This environment includes the current federal and state programs and recognition of the uncertainty generated by the continual development of new programs. Our understanding of the general stance currently being taken by federal and state officials is that voluntary programs will be expanded and operated for the next five years or so. If this approach proves to be inadequate, movement will be toward a regulatory approach, which will provide an interesting challenge for the bureaucrats, and for modelers.

Environmental Interactions

Soil erosion is not the farmers' only environmental concern. They are also faced with recommendations or regulations on the appropriate use of pesticides. These choices are not independent of the soil erosion control practices chosen. For example, the shift from the conventional plowing to no-till operation involves the increased use of herbicides and perhaps insecticides, fungicides and rodenticides and changes in application techniques.

Stochastic Considerations

A number of the physical phenomena involved are not deterministic. The weather pattern in a given year may impact the yields of each tillage practice differently. For example, the weather will influence the movement of plant nutrients through the soil, the effectiveness of herbicides and insecticides, as well as planting and harvesting dates. Some systems are well adapted to dry years, others to wet years. While the previous elements of our modeling enterprise may be handled by artful adaptations of the linear programming process, here we need to shift other types of models including quadratic programming with risk considerations. This may be a particularly fruitful area in that yields are more variable with some conservation tillage practices.

As economists we recognize, but only occasionally model, the stochastic market environment in which the firm operates. We need to know the farmers' reaction to changes in prices of inputs and outputs and whether soil conservation choices will impact market prices (Seitz et al.).

Beyond Economics

Thus far, we have concentrated on translating the various factors relevant to the soil erosion control decision into economic terms. It is important to recognize that this class of decision is not made solely on the basis of economics (Seitz, Gardner, van Es). There is currently discussion about the need for a conservation ethic. The operator may feel peer pressure, pressure from owners, or may have a strong personal preference for certain practices over others. Many farmers have a preference for a cleanly tilled field and straight rows. To deliberately shift to methods resulting in a trashy field and curved rows may be difficult.

In essence we are painting a picture of a farm decision process that is much more complex than represented by the models we find in the literature. As we construct more appropriate models of the overall farm planning process, we may be able to improve our explanation of soil conservation decisions made by the farm operator. We also may identify changes needed in these decisions. We still have a long way to go to develop the types of models needed to characterize the full range of considerations that impact on farmers' decisions regarding soil conservation and to enable us to perform our educational function more effectively.

References

Anonymous. "Why I Switched to No-till Beans." *Kentucky Farmer*, Jan. 1979, p. 36.

Burt, Oscar R. *A Farm Level Study in the Economics of Soil Conservation: The Palouse of the Northwest.* Unpublished manuscript, Dep. Agr. Econ., Montana State University, 1980.

Cole, Pam. "He Makes More Money on No-till Corn." *Prairie Farmer*, 1980, p. 15.

Comptroller General of the United States. *To Protect Tomorrow's Food Supply, Soil Conservation Needs Priority Attention.* Report to the Congress. CED-77-30, Washington, D.C., 1977.

Fisher, V., J. Boyle, M. Schulman, M. Bucuvalas. *A Survey of the Public's Attitudes Toward Soil, Water, and Renewable Resources Conservation Policy.* New York: Louis Harris & Associates, Dec. 1979.

Frohberg, Klaus K. *Optimal Soil Loss over Time from a Societal Viewpoint.* Ph.D. thesis, University of Illinois, 1977.

Frohberg, Klaus K., and Earl R. Swanson. *A Method for Determining the Optimum Rate of Soil Erosion.* Dep. Agr. Econ. AERR-161, University of Illinois, 1979.

Gogerty, Rex. "No-till: A Personal View." *The Furrow*, 1979, p. 22.

Guntermann, Karl, M. T. Lee, A. S. Narayanan, and E. R. Swanson. *Soil Loss from Illinois Farms: Economic Analysis of Productivity Loss and Sedimentation Damage.* Chicago: Illinois Institute for Environmental Quality, IIEQ Document No. 74-62, 1974.

Held, Burnell R., and Marion Clawson. *Soil Conservation in Perspective.* Baltimore, Md.: Johns Hopkins University Press, 1965.

Hoover, Herbert, and Marc Wiitala. *Operator and Landlord Participation in Soil Erosion Control in the Maple Creek Watershed in Northeast Nebraska.* Washington, D.C.: U.S. Department of Agriculture, ESCS Staff Rep. NRED 80-4, March 1980.

Nelson, M. C., and W. D. Seitz. "An Economic Analysis of Soil Erosion Control in a Watershed Representing

Corn Belt Conditions." *North Cent. J. Agr. Econ.* 1(1979):173–86.

North Central Farm Management Research Committee. *Conservation Problems and Achievements on Selected Midwestern Farms.* Ohio State University Agr. Exp. Sta. Circular 86, 1951(N. Cent. Rgnl. Pub. No. 23).

Pollard, R. W., B. M. H. Sharp, and F. W. Madison. "Farmers' Experience with Conservation Tillage: A Wisconsin Survey." *J. Soil and Water Conserv.* 34(1979):215–19.

Seitz, W. D., D. M. Gardner, and J. C. van Es. *Implementing Nonpoint Source Pollution Policies: Recognizing Farmers' Attitudes.* Athens, Georgia: U.S. Environmental Protection Agency, forthcoming.

Seitz, W. D., et al. *Alternative Policies for Controlling Nonpoint Agricultural Sources of Water Pollution.* Washington, D.C.: U.S. Environmental Protection Agency, EPA-600/5-78-005.

Swanson, E. R., and C. E. Harshbarger. "An Economic Analysis of Effects of Soil Loss on Crop Yields." *J. Soil and Water Conserv.* 19(1964):183–86.

Timmons, John F. "Protecting Agriculture's Natural Resource Base." *J. Soil and Water Conserv.* 35(1980):5–11.

Turney, Henry. "Land Use Planning: A Farmer-Rancher View." *J. Soil and Water Conserv.* 32(1977):3–4.

U.S. Congress, Senate. Committee on Agriculture and Forestry. *Minimum Tillage: A Preliminary Technology Assessment.* 94th Congress, 1st sess., 25 Sept. 1975.

U.S. Department of Agriculture. *Soil and Water Resources Conservation Act Appraisal 1980,* Review, draft parts I and II and summary. Washington, D.C., 1980.

Vogel, John. "If You're Talking Money, Minimum Tillage Nets the Most." *Prairie Farmer,* 151(1979), p. 16.

White, G. B., and E. J. Partenheimer. "Economic Impacts of Erosion and Sedimentation Control Plans: Case Studies of Pennsylvania Dairy Farms." *J. Soil and Water Conserv.* 35(1980):76–78.

Willis, C. E., and R. D. Perlock. "A Comparison of Generating Techniques and Goal Programming for Public Investment, Multiple Objective Decision Making." *Amer. J. Agr. Econ.* 63(1980):66–74.

Young, Douglas, Daniel Taylor, and David Holland. "Evaluating the Long-Term Economic and Physical Performance of Alternative Tillage Systems in the Palouse." Dep. Agr. Econ. paper prepared for 1979 STEEP Review, Washington State University, 1979.

The Impact of Landownership Factors on Soil Conservation: Discussion

Daniel Bromley

The question of resource use patterns as influenced by institutional arrangements is at the core of any understanding of natural resource economics. All of the conventional explanatory variables, such as rates of time preference, prices, income, user costs, and risk preferences, are meaningless without being related to the nature of the decision-making unit. A family is clearly a different decision unit than is a corporation, and a partnership is different still.

Lee is to be commended for beginning an investigation which, if it ever succeeds, will be indispensible to our understanding of important resource use issues. While I am most supportive of the general enterprise, I am troubled by the specifics of her approach. In these brief comments I will raise questions about the empirical models, the data, and the conclusions. I will then offer a few closing remarks.

The Empirical Models

I am disappointed that she did not present the estimating equations for her two models, and in their absence it is not always clear what is being regressed on what. In Model I it is clear that non-family corporations are the excluded class in her dummy regression. Coefficients for other ownership classes then reflect differences in the mean rate of erosion for each class as against the excluded class. However, it would have been better if she had employed the more appropriate stance of testing the hypothesis that these other coefficients are equal to zero. While formally equivalent, it would have been clearer when consulting her table.

Turning to Model II, she tested differences in soil erosion among income and tenure variables, but only the results for income are presented in table 2. This is confusing since the discussion pertains to results which were not presented in the table. We are told that the "relationship between net farm income and mean levels of erosion appeared to depend on the tenure category of the landowner." Yet, the analysis behind this observation is not presented.

The Data

The universal soil loss equation was utilized to determine rainfall erosion data. It bears remembering that this relationship was derived from—and only really applies to—soil conditions in the upper Midwest. I am therefore worried about what went into the most crucial variable in her entire investigation.

Of equal concern is the partition of the explanatory variable. My friends who do empirical work in other areas of economics are always envious of the data base available to agricultural economists. But the bad news is that we often end up with data which are mere numbers rather than useful scientific information. I worry about the classification of ownership in this work. The ownership classes are legal descriptions which attempt to define different types of decision units, when in fact they merely define different types of income and cost accounting practices. I am skeptical that institutional arrangements designed for tax purposes are relevant to how people use their soil resource.

Conclusions

In a suggestion for more research, she states that age and education are important variables which ought to be included. One of these—age—follows from our neoclassical orthodoxy which places great stock in one's rate of time preference. Excluded, of course, because we are loathe to put it in our models, is ethnicity. We have found in Wisconsin some differences

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in attitudes about—and thus behavior with respect to—soil erosion across ethnic groupings. Additionally, she mentions changing structural characteristics in agriculture as it relates to erosion. However, this seems of a rather longer-run nature than our data will reveal. I suggest that it is preferable to do impeccable cross-sectional analysis of existing structural differences. Then, employ the work of others to forecast likely structural changes, and finally infer what those structural changes would mean for erosion in light of our cross-sectional models.

In closing, I find that her analysis does not give me sufficient basis for accepting her results. There are severe data problems. Nowhere in tables 1 and 2 are we shown standard errors for the estimates which have been derived. And the very important results relating erosion, income, and ownership class were not presented. Moreover, the definitions of the explanatory variables are too gross to have analytical meaning. I do, however, applaud Lee's efforts at attempting this general kind of analysis. I urge her to continue to pursue the matter. But I also urge her to disaggregate her explanatory variables into analytically relevant categories.

Conversion of Noncropland to Cropland: The Prospects, Alternatives, and Implications: Discussion

Pierre Crosson

Shulstad and May have done a good job of identifying and giving perspective to the principal issues this country likely will face over the next several decades in managing its agricultural land and water resources. Their paper is well done, and I have no quarrel with either the main thrust or the details of their argument. I propose, rather, to use the paper as a point of departure to discuss some of the research and policy issues the paper suggests.

Current trends in demand for U.S. exports of grains and soybeans, combined with current trends in per acre yields of these crops suggest strongly that the demand for cropland will increase by tens of millions of acres over the next two or three decades. Judgments of the amount of the increase depend upon the details of one's expectations about export growth and yields, but I think it not unlikely that demand for harvested cropland could increase to 400 million acres by the first decade of the next century, some 60 million more acres than were harvested in 1979. Since our present cropland base is fully utilized, the additional cropland would have to come from conversion of land now in some other use.

The Soil Conservation Service's Natural Resources Inventory (NRI) indicated that under price, cost and yield conditions of the mid-1970s the nation had 127 million acres of land in pasture, forest and range that could be converted economically to cropland. This would seem to indicate a reserve more than adequate to accommodate any likely increase in demand for cropland over the next twenty or thirty years.

However, Shulstad's and May's estimates of potential cropland in the Mississippi Delta raise a question about the NRI's figures. Under the most favorable assumptions about crop and input prices, conversion costs and yields (assumptions more favorable than the conditions underlying the NRI figures), Shulstad and May estimate potential cropland in the Delta to be only about 10% of present supply. According to the NRI, in 1977 potential cropland in the Delta states of Arkansas, Louisiana, and Mississippi was 48% of supply. One would expect potential in the Delta proper to be less than in the Delta states as a whole, but I doubt that this explains much of the observed discrepancy.

The estimate of Shulstad and May is based on a detailed study. If one had to choose between their estimate and those in the NRI I believe theirs would have to be preferred. If this is correct then conversion of cropland in the Delta on the scale indicated in the NRI would entail substantially higher costs and would be undertaken only if crop prices were much higher than the prices underlying the NRI figures.

The contrast between the estimates of the NRI and of Shulstad and May for the Mississippi Delta suggests that detailed studies of potential cropland are needed in other major crop producing regions. The southeast, northern and southern plains, and cornbelt states, other than Iowa, are obvious candidates. (Iowa already has been studied by Amos, as Shulstad and May note.) If the nation's supply of potential cropland is as inelastic as the work of Shulstad, May, and Amos suggests, the sooner we know about it the better. Continued reliance on the NRI estimates would underestimate the pressure of current trends in exports and yields on the agricultural land base.

Shulstad and May, and Amos in his study of land conversion potential in Iowa, also estimate the increases in erosion that would result from converting land to crops. In the Delta conversion of all the potential land would increase erosion by 14 tons per acre on average.

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In Iowa erosion would rise to 15-to-98 tons per acre. While neither of the studies attempted to measure either the off-farm or on-farm costs of these rates of erosion, these costs clearly could be high. Moreover both studies indicate that the cost to farmers of holding erosion within SCS desired limits (5 tons per acre or less) would be high. Consequently farmers will not do this voluntarily.

The prospect that conversion of potential cropland to crops will impose sharply higher costs of erosion indicates that we need to know much more about these costs, both on-farm and off-farm. In this connection, the research now under way in the USDA on the relationship between soil erosion and yields, referred to by Shulstad and May, is most welcome. I hope it will be vigorously pursued. Because of the strong advantage of conservation tillage in reducing erosion, we also need to know more about the economics of this technology relative to conventional tillage. Judging from its rapid spread since the mid-1960s conservation tillage has significant economic advantages under many circumstances. If we knew more about these circumstances we could identify the factors limiting further spread of conservation tillage and could design research to extend these limits. This route offers a way to deal with the erosion problem which works with the farmer's economic interest rather than against it as, e.g., erosion control regulations or taxes on excess soil loss would do.

If we think the mounting pressure on the nation's agricultural land base will be too great we could seek to reduce it by limiting the expansion of exports or stimulating faster yield increases, or by some combination, of course. Export quotas would stir a political hornet's nest, and in any case go against the deep grain of American foreign trade policy. Imposition of an export tax to reflect the costs of erosion and other externalities is appealing in principle, but would be extraordinarily difficult in practice, in large part because we do not know these costs. An expanded effort to accelerate the growth of food production in developing countries is an attractive alternative, for reasons that go beyond reducing the pressure on the agricultural land base. If that pressure is high enough to be troublesome it will be associated with high crop prices, which should reduce farmer opposition to a policy which over the long term would reduce the growth of their foreign markets.

Policies to stimulate faster growth in crop yields are the most attractive of all in my judgment. The social return to agricultural research continues generally high in the United States (Evenson, Waggoner and Ruttan). If the economic and environmental costs of agricultural land rise, as my interpretation of Shulstad's and May's results suggests, the return over the next several decades to research on yield-increasing technologies may be very high indeed. In this connection, Shulstad's and May's conclusions about the yield-increasing effects of investments in land-forming are interesting. These investments evidently begin to pay off in three or four years, while the pay-off to investment in developing new technologies is much longer delayed. The studies mentioned earlier of land conversion potential in the Corn Belt and other main crop-producing regions should incorporate analysis of the yield-increasing potential of investments in land-forming. This potential may be significant. Better knowledge of the potential likely would suggest policies for quick capture of it.

Reference

Evenson, Robert E., Paul E. Waggoner, Vernon W. Ruttan. "Economic Benefits from Research: An Example from Agriculture." *Science*, vol. 205, 14 Sept. 1979, pp. 1101–07.

Economics of Soil Conservation from the Farmer's Perspective: Discussion

Gordon C. Rausser

Unfortunately, Seitz and Swanson (hereafter referred to as SS) fail to provide us with a clear focus of the soil conservation problem or, for that matter, the principal issues that arise in attempting to solve the problem. Hence, in these comments it seems appropriate to address first the nature of the soil conservation problem, and then briefly examine some major analytical issues and critique the SS survey.[1]

Soil conservation can be thought of loosely as a redistribution of resource use into the future relative to the present and is the opposite of depletion. Soil conservation is, in effect, a problem in capital theory whose operational implementation is the management of soil resource over time. Since soil conservation is inherently dynamic, a number of thorny issues arise in the intertemporal specification of the problem. Soil conservation is most certainly a multidimensional problem which encompasses far more than just loss tolerance levels. The trade-offs faced are similar to most capital theory problems but in the case of soil conservation are compounded by the lack of knowledge, measurement problems, and important distinctions between quantity and quality dimensions.

In the above setting, a number of perspectives are possible. SS provide us with two perspectives. They begin their paper with a public policy perspective arguing that an understanding of farmers' behavior is essential in the development of policy instruments that will achieve social objectives. However, they end their paper with an educational function perspective in which we are charged the responsibility of developing optimal private strategies that might be pursued by farmers who fail to have adequate knowledge or know their own best interest. In this discussion, I will focus on the first perspective since it subsumes the second.

The public policy perspective requires some clarity of thought in terms of the nature, extent, and basis for market failure. Market failure can be interpreted broadly in terms of conventional exchange markets, contract markets, and political markets. In some quarters, the perception is that existing institutional and incentive structures result in suboptimal management of soil resources. Divergences between social and private net benefits may be caused by tenure, credit rationing, and uncertainty features of the agricultural sector; by discrepancies between the societal planning horizon and the planning horizons (myopic) of individual farms; by discrepancies between farmers' time preferences and the social rate of time preference; by externalities (runoff and sedimentation); by the differences between public and private risk preferences; and by "price divergences" generated from "political markets" reflecting transfers of wealth via governmental intervention (price supports and deficiency payments). What is needed at this juncture are fewer surveys and more serious measurements of such divergences.

The extreme heterogeneity and complexity of soil resources in an operational setting calls for "enlightened" partial analyses. The focus of such analyses should be on the relationships among important variables of the soil resource which trace systematically through time the important factors affecting productivity. As SS note, many of these relationships have not been estimated empirically. Nevertheless, an important first step in any empirical measurement is the conceptualization of the phenomenon to be measured. Here, we must recognize that soil is not a single resource but a set of individual interrelated components which have both stock and flow dimensions. Moreover, what information is available can be em-

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[1] A more detailed set of comments may be obtained from the author upon request.

ployed under uncertainty using advancements that have been made in stochastic models over the last decade.

An important but neglected issue relates to the joint product goods and bads associated with a number of important inputs, e.g., water, chemical pesticides, and certain types of machinery (Rausser and Lapan). In this framework, soil quality is not simply an afterthought but assumes direct importance. Unfortunately, soil quality is not easily monitored. Improvements in technology or the expectation of such improvements, for example, may mean that yields increase even if soil quality falls; hence, yields are not an unequivocal signal of the state of soil quality. Such effects may mean that soil quality is not incorporated in land values in an easily discernible manner.

Given the above brief sketch, what does the survey by SS offer us? The results that they summarize certainly make a case for governmental intervention by substantiating the weakness of private incentives for soil conservation. By themselves, however, these results do not necessarily imply a problem; if farmers are operating at or near an optimum, incentives for change ought to be weak. Only by testing properly formulated hypotheses can we hope to accumulate evidence of market failure and inefficient behavior of private agents. The principal message of the SS survey is that we need basic conceptual and empirical work to formulate more accurate models characterizing private behavior.

The directions for future modeling efforts outlined by SS can be seriously challenged. To be sure, farm LP models can only be of limited value in understanding soil conservation. Management of the soil resource is inherently dynamic, and thus static constructs modified by various bells and whistles provide little insight. Furthermore, the technique perspective implied by such recommendations as goal and quadratic programming methods strikes me as inappropriate. Similarly, the addition of soil-loss constraints in static models most likely detracts rather than enhances our understanding of the basic trade-offs that must be evaluated. Arbitrary levels of soil loss have little economic meaning, and most certainly such measures should be generated endogenously in any "sufficiently" accurate modeling approximation to the soil conservation problem.

While some areas of investigation suggested by SS appear promising, others should simply be dismissed. For example, the argument that farm owners over sixty-five years of age are not particularly concerned with long-run impacts of their land utilization practices runs contrary to available empirical evidence and intuition. Owners certainly place some value on their heirs; and since the quality of land transfer from one generation to another constitutes a portion of inherited wealth, sound judgment suggests that this argument should not weigh heavily in our investigations of soil conservation. It seems far more likely that land values which fail to reflect soil quality accurately contribute more as the source of this problem than does the age of landowners.

Reference

Rausser, Gordon C., and Harvey Lapan. "Natural Resources, Goods, Bads, and Alternative Institutional Frameworks." Dep. Agr. Econ. Work. Pap. No. 89, University of California, Berkeley, June 1980.

Abstracts

AAEA Teaching Workshop

(Southern Illinois University, Carbondale, 24–26 July 1980)

Evaluating Student Participatory Models for Teaching Economic Theory: Some Preliminary Results. Josef M. Broder (University of Georgia)
This paper discusses the purpose, design, implementation, and evaluation of student participatory models used to supplement traditional approaches to teaching economic theory. Preliminary evaluations indicated that students found these models useful and recommended their expanded use. A reduction in cognitive skill differences among students with unequal human capital was attributed to the models.

Teaching Agribusiness Management: Junior, Senior Level. Dennis M. Conley (University of Illinois)
The paper focused on the use of a computer game and field trips as tools for experimental learning. The game integrates lecture material on financial analysis, pricing and margins, inventory management, planning and organizing, leadership, and communication skills. The game also simulates experience in decision making and it reinforces the learning process.

Field trips are used to identify agribusiness industry and the internal operations of a firm. Students learn of potential employers' expectations and what course material is needed. The students then recognize the usefulness of certain course topics. An agribusiness management game and field trips are significant pedagogical tools.

Using Guided Design in a Classroom. Carl O'Connor (Oregon State University)
Guided design is an educational strategy that makes it possible for teachers to accomplish simultaneously two goals which have severely resisted integration: (*a*) teaching subject matter and (*b*) developing the decision-making skills required to apply what has been learned to the solution of real-world problems. The concept was first introduced into agricultural economics literature in 1976.

This teaching technique is useful in recitation classes, where the teaching goal is to extend the lecture and the material assigned as reading to an applied problem requiring decision-making skills. In guided design, a series of open-ended questions and feedback gradually expose a complex problem setting that the student must eventually grasp as a whole. One of the objectives of using this technique is to help the student handle ambiguity, an inherent part of almost all professional situations.

With guided design, the teacher models professional reasoning and shows students how the material they study can be used to make better decisions. This process increases the students' motivation and improves the retention of subject matter.

Selecting a Teaching Method. Carl O'Connor (Oregon State University)
College and university teachers are turning to alternative approaches to the conventional lecture. This response is being triggered by the increased demand by students for a "better education" in line with the demands and prerequisites of employers to come prepared to work with operational skills and knowledge. Other reasons for this pressure to consider alternative teaching methods are factors such as cost effectiveness, minimal standards and competency that must be reached by all students taking the course, administrative review and evaluation reports of teaching performance, peer pressure, and student feedback.

Three alternative teaching methods were demonstrated at this workshop: (*a*) conventional lecture, (*b*) audio-tutorial, and (*c*) guided design. To evaluate these methods, a matrix of thirty potentially important criteria are suggested.

Communicating in the Classroom. W. David Downey (Purdue University)
Using lecture, discussion, and small group exercises, basic concepts of communicating were demonstrated. Attention focused upon models of classroom communications, factors affecting communications, and methods of communications. These were examined in terms of classroom size and other variables. Participants presented and exchanged teaching ideas.

Agricultural Marketing Block Program. Thomas I. Gunn (California State University-Fresno)
An innovation in classroom instruction, the Agricultural Marketing Block Program by the Department of Agricultural Economics at California State University-Fresno, began during the spring semester 1975. The block is planned to bridge the gap between classroom instruction and the world of agricultural business and marketing.

The block program departs from the usual lecture format course. Some lectures are presented by the instructor, but extensive utilization is made of

closed-circuit television, field trips, future-trading games, roundtable discussions, student presentations, class demonstrations, educational films, and the participation of resource people from both inside and outside the university. Objectives, characteristics, evaluation, and potential uses of the block program are discussed.

Lecturing. L. H. Newcomb (Ohio State University)
The lecture method of teaching has situations for which it is suitable and unsuitable. In addition, there are a number of problems which must be solved. These problems are (*a*) inadequate preparation, (*b*) sloppy organization, (*c*) lack of animation, (*d*) failure to converse with the audience, (*e*) lack of clear illustrations, (*f*) monotonous tone, (*g*) too much or too little information presented, and (*h*) information presented too fast or too slowly.

Professors need to examine the characteristics of outstanding lecturers and compare those characteristics to their own individual characteristics. When this comparison reveals substantial differences, then professors need to be sure they are not using a method that unduly exploits their weaknesses. Most people will find that straight lecturing is seldom effective and need to consider a number of complements to the lecture. Some of these complements are boardwork, transparencies, slides, charts, concrete frames of reference, specimens, guests, role plays or skits, questions, and problems.

Identifying Learning Conditions. L. H. Newcomb (Ohio State University)
There are a number of conditions which affect teaching and learning. Some of these conditions deal directly with the student as a learner, while others deal specifically with the behaviors of teachers.

Teacher behaviors which are consistently correlated with improved student behavior are clarity, variability, enthusiasm, task-oriented and/or businesslike behaviors, student's opportunity to learn criterion material, and absence of excessive negative criticism.

Group Discussion: Marketing. Andrew Novakovic, moderator (Cornell University)
The purpose of the group discussion was to share course outlines, lecture materials, class exercises, and innovative ideas on teaching among instructors of agricultural marketing. The results of two surveys were presented. The first was a survey of marketing courses that included sixty-four undergraduate course outlines from forty-two universities (Cornell University). The second survey was of class exercises used in introductory agricultural marketing courses at thirteen universities (Purdue University). Further discussion in the group involved a variety of topics, including the appropriate orientation of marketing courses to meet the needs of a diverse student body, the use of games, field trips, labs, and the like to illustrate important concepts in marketing, and the development of instructional materials and readings for specific topics in agricultural marketing.

Experimental Learning Aided by a Microcomputer. D. D. Osburn, K. C. Schneeberger, M. R. Wilsdorf, and E. S. Reber (University of Missouri)
The use of the microcomputer to teach and reinforce concepts in farm management and agricultural finance courses is discussed and compared to other computer-assisted instructional techniques. Six microcomputer programs in the farm management/farm finance-related areas were written to be as user-oriented as possible so that students could operate them with a minimum of instruction. Procedures for effective use and evaluation of microcomputers were discussed.

The use of the microcomputer appeared to increase motivation among students. Other benefits included: (*a*) sensitivity analyses of several types were more readily achieved and observed by students as they changed input data, (*b*) students were able to approximate the real world with greater ease, and (*c*) students could put theory to a test in the models.

Requisites for Successful Undergraduate Programs in Agricultural Economics. Thomas R. Pierson (Michigan State University)
The following assumptions describe the likely planning environment for undergraduate program development during the 1980s: restricted resources from conventional sources of funding, limited growth in the numbers of traditional students, moderate growth of "mainstream" employment areas, increased opportunities to provide educational services for "new" clientele groups, the potential for stronger agricultural economics/industry and public sector relationships, and opportunities for effective market segmentation of educational programs.

Successful programs will serve the following requisite needs of students, employers, and society: quality advising and faculty contact with students, improved communication with potential employers and society, emphasis on the teaching of marketable entry-level and life-long career skills coupled with the development of general living skills and philosophies, and greater effectiveness in the recruiting and job placement processes.

Agricultural Economics in the 1980s. Phillip F. Sisson (Quaker Oats Company)
The dynamic changes in American agriculture over the past decade have vastly altered the analytical

approach of the agricultural economist employed in industry. No longer are the changes in domestic requirements the prime mover of commodity prices. Rather, the demand emanating from the foreign sector and the outlook for production in the major importing and exporting nations have surfaced as the important areas of analysis.

A better understanding of new factors influencing agriculture and agricultural trade is needed. These include foreign agricultural supply and demand, internal agricultural policies of other nations, trade and trade policies, weather and climate, foreign currencies, and precious metals.

An Audio-Visual, Self-Learning Program for Beginning Students in Agricultural Economics. Kelso L. Wessel (Ohio State University)

This paper describes the development, cost, and personnel required for Audio Video Institutional Supplement (AVIS) in a beginning agricultural economics course. Evaluation of AVIS was made in terms of study habits, use of student workbooks, problems completed and student performance. AVIS is an important supplement for students who encounter difficulty understanding the concepts from traditional type lectures. Student reaction to AVIS was very favorable.

Toward Excellence in Teaching. Neil E. Harl (Iowa State University)

Improving the effectiveness of teaching involves disaggregating the teaching-learning function into three components: the student, the educator, and the instructional process, all in the setting of the academic institutions.

The modern university, the major academic institution, occupies a unique role with respect to its teaching function. The essential mission of the university is the renewal of civilization by developing the potential for creative minds capable of critical and independent thought, with the ability to communicate effectively. Thus, the teaching-learning process should produce in students: (*a*) the ability to think and reason—creatively, analytically, thoroughly, and with reasonable alacrity, (*b*) the ability to communicate in writing—accurately, precisely, and with a richness worthy of the language, and (*c*) the ability to speak in a clear, articulate, and convincing fashion.

Excellence in instruction is difficult to define but includes, on the part of the educator, knowledge of subject matter, the ability to communicate with students, a boundless enthusiasm for the discipline and its power, a continuing interest in students, an ability to make the educational process interesting, the quality of encouraging students to search widely for grist for the analytical mill, and a professional approach to the teaching-learning process.

Curriculum for the 1980s. Ronald D. Kay (Texas A&M University)

An agricultural economics curriculum for the 1980s will need to recognize the trend toward nonrural backgrounds among many of our students, changes in the profession, and the market for our graduates. In addition to changing the content of many existing courses, additional courses may be required in the areas of technical agriculture, communications and interpersonal skills, computer technology and applications, accounting, and business management. Good teaching will also be needed to strengthen and improve the product of any curriculum.

Perspectives on Resource Economics Teaching. John A. Miranowski (Iowa State University)

The application of economic concepts to natural resource and environmental decision making is a relatively new field of teaching specialization that continues to undergo dramatic change. The objective of this session was to determine what educational methods and materials are useful for particular instructors and why. Many of the participants believed that capitalizing on the diversity of the students through "guided design" discussions was an effective, although sometimes difficult, teaching strategy. Also, illustrations with actual resource problems were particularly helpful.

Abstracts

Symposia

Agricultural Estate Planning: A Micro Perspective. Stephen F. Matthews, chairperson (University of Missouri); David Reinders, Michael Boehlje, and Neil E. Harl (Iowa State University); C. Allen Bock (University of Illinois); and J. W. Looney (Kansas State University)

Some estate planning decisions are made more easily if projected results of various options can be quantified. Computers can be useful by producing such specific information as estate tax costs of different alternatives under varying assumptions. Computer programs such as Iowa's Computer Assisted Estate Analysis can be of assistance but cannot replace professional counsel because computers cannot exercise judgment.

A "disclaimer" is a refusal to accept property otherwise passing to an individual by gift or inheritance. The property passes to a third party chosen by law rather than by the disclaimer. A "qualified disclaimer" occurs where the indirect transfer from the disclaimant to the third party is not treated as a taxable transfer for gift or estate tax purposes. Qualified disclaimers can provide built-in flexibility, rectify improper funding of the marital deduction, add assets to trusts with income to the surviving spouse, avoid generation skipping tax traps, modify powers that could have adverse tax consequences, and insulate property from creditors.

Internal Revenue Code Section 2032A "use valuation" allows qualifying farmland to be valued for estate tax purposes significantly below its value on the auction block. In practice, use valuation has resulted in savings to taxpayers beyond original predictions. Newly issued final regulations (31 July 1980) clarify some of the ambiguity present in the original legislation. These regulations state, *inter alia*, that simultaneous activities of multiple family members cannot be aggregated to find the requisite material participation and that the availability of cash rental data for comparable property is a prerequisite for utilizing the formula method of use valuation.

Export Marketing Performance of the Major Grain-Trading Nations. Lowell D. Hill, chairperson (University of Illinois), Reynold P. Dahl (University of Minnesota), William W. Wilson (North Dakota State University), Parr Parsons and Michael Cook (Texas A&M University), Leonard Schruben (Kansas State University), Ed Tyrchniewicz (University of Manitoba), and Alex McCalla (University of California-Davis)

Recent congressional interest in the creation of a national grain-exporting agency has focused attention on methods for evaluating alternative grain-marketing systems. The conventional structure-implies-conduct-implies-performance approach fails to address a number of issues peculiar to the international grain trade. The organization of this symposium resulted from a felt need for criteria and methodology useful in assessing grain-marketing system performance directly.

Four principal points were raised. First, the perfectly competitive model may be useful as a benchmark in evaluating the pricing efficiency of the U.S. system. The first paper concluded that price transmission performance between export terminals and county elevators in the United States closely approximates a hypothetical perfectly competitive market. Second, a comparison of alternative system organization can be drawn by contrasting pricing performance between the U.S. and Canadian systems. The second paper argued that, exclusive of transportation costs, price differences in the two systems are not statistically significant. Third, papers using the Australian and Argentinian systems as examples contended that a system performance evaluation cannot be made without a full appraisal of the economic and agricultural policy environment in which it operates. The final paper provided some subjective insights into possible problems and conflicts inherent in a shift in the U.S. system from private enterprise to one with more active government involvement.

Foreign Fishing Policy within the 200-Mile Limit: Its Impact on Domestic Fishery Development, Processing, and Consumer Welfare. Jon M. Conrad, chairperson (Cornell University), Mort Miller (National Marine Fisheries Service, Washington, D.C.), Dan Huppert (National Marine Fisheries Service, La Jolla), Bob Stokes (University of Washington), and Virgil Norton (University of Maryland)

Miller sought to (*a*) define the nature and scope of current foreign fishing within the 200-mile zone, (*b*) review the fee structure facing foreign vessels seeking to fish in U.S. waters, and (*c*) discuss some elements of the Breaux bill which seeks to amend the FCMA. Japan was the major foreign fishing nation, accounting for about 56% of foreign catch by value.

A foreign vessel is charged $1.00 per gross ton for a permit to fish in U.S. waters and 3½% of the ex-vessel value of the allocated catch (based on U.S. ex-vessel prices). Recently, a 20% surcharge on fees has been added with surcharge revenues going into a gear damage fund to compensate U.S. fishermen for gear damaged or lost by foreign vessels or severe weather. Estimates of the costs of enforcement vary, depending on methods of prorating Coast Guard vessel costs. One intermediate estimate puts the cost of enforcement at $65 million or

3.6 times the revenue generated by foreign fishing fees.

Huppert noted that foreign vessels off the coasts of Washington, Oregon, and California were predominately taking high volume/lower value species and processing them into frozen products at sea. Rapid processing is important to ensure the quality of many species such as Pacific hake. Development of large trawler/processing capacity may be essential if the United States is to harvest economically certain species. Alternatively, joint ventures where foreign processing vessels rely on catch from U.S. harvesting vessels might also play a greater role in domestic fishery development.

Stokes noted that development of U.S. capacity and interest in the Pacific groundfisheries has been slower than expected. As a result, policies governing foreign access to "surplus stocks" will be of continued importance. Consistent with the intent of FCMA the current fees are nominal, having little to do with the extraction of resource rents or efficient resource allocation. The State Department and other agencies may actually prefer the present nominal structure in that it allows them a certain amount of discretion in dealing with foreign governments seeking surplus allocations. Access to U.S. fish stocks may be part of a quid pro quo in tariff and trade negotiations. Stokes outlined an applied research agenda.

Norton concluded the symposium echoing some of the comments of earlier panelists calling for research into (*a*) the markets for auctioning foreign fishing rights, (*b*) the distribution of benefits between fishermen, processors, and consumers, and (*c*) the role that foreign fishing and domestic policies should play in achieving overall management objectives. Norton felt it important that the NMFS increase its capability to perform more detailed and longer-term analysis of the economic effects of alternative foreign and domestic fishing policies.

Preliminary Results from the Nationwide Food Consumption Survey 1977–78. Robert O. Herrmann, chairperson (Pennsylvania State University), Robert L. Rizek (SEA USDA), Rueben C. Buse (University of Wisconsin), Stanley R. Johnson (University of Missouri), and Barry M. Popkin (University of North Carolina)
This symposium discussed the progress of the 1977–78 USDA Nationwide Food Consumption Survey, methodological problems in the analysis of households analysis, and planned research with the survey data.

Rizek suggested, and it was generally agreed, that research is needed on the data needs of food survey data users and on ways to speed the collection and release of survey data. Rizek also noted the need for more research on household food waste.

Both Buse and Johnson argued that many methodological problems remain in the analysis of household food consumption data. These arise out of the nature of current consumption theory, the characteristics of data describing household consumption and household demographic characteristics, and the statistical tools available for data analysis.

It was suggested by Popkin that the 1977–78 survey is not completely adequate either for nutritional analyses or for study of program impacts. Better indicators of nutritional outcomes (e.g., measured height and weight) and information on health problems or concerns are needed. For program analyses, historical information on participation is needed as well as data to permit control of factors the effects of which would otherwise be attributed to program participation.

Methodological and Evaluation Issues in International Farming Systems Research. B. F. Stanton, chairperson (Cornell University), Larry Harrington (International Maize and Wheat Improvement Center, Mexico), Edward Price (International Rice Research Institute, Philippines), Richard Bernstein (Central Research Institute of Agriculture, Indonesia), and Earl D. Kellogg (University of Illinois)
Major issues regarding the methodologies to use in studying farming systems in a variety of settings were central to this symposium. Concentrating on target enterprises as they relate to the whole farming system was preferred over the holistic approach of trying to consider simultaneously all the variables that may affect a farming system. Target groups of farmers were identified in two ways: by common agro-climatic and socioeconomic factors and major differences in crops or livestock in the farming systems. These approaches may finally yield similar results but require different data for implementation.

There were differences of opinion regarding the usefulness of attempting to define productive research directions a priori. Efforts to prescreen technology and collect data regarding major farmer problems and goals by survey was given priority by some. Other participants thought scientists' observations of farmer trials yielded more useful information. Most agreed that economists should work with other agricultural scientists in identifying key problems and possibilities for research.

The need for evaluation methodologies that can be used by persons with modest economic training was emphasized. In some national programs where research staff resources are thin, standardized data collection and analysis procedures making use of programmable calculators can be emphasized. Evaluation of new technology as part of a farming system managed by current farmers was discussed. The problem of variability among farms and over time was recognized. The need for evaluation methods which focus on (*a*) stability and flexiblity of farming systems over wider areas, and (*b*) the

productivity of international and national farming system programs were considered.

Modeling Energy Use at the Farm Level with Emphasis on Crop Farms. Ken Schneeberger and Herman Workman, chairpersons (University of Missouri), Vernon Eidman (University of Minnesota), Robert Peart (Purdue University), Marvin Duncan (Kansas City Federal Reserve Bank), and John Holt (University of Florida)

The profession is poorly prepared to respond to questions on the economic feasibility of alternative conservation and self-sufficiency scenarios. Any modeling effort must be done in the context of the food and fiber system. As the price of energy relative to other resources changes, it may be economic to shift some functions from off-farm firms to farmers, and vice versa.

Three types of farm level studies are (*a*) technology assessment, (*b*) whole farm organization, and (*c*) structure studies. Technology assessment refers to studies that evaluate only one part of the business, e.g., solar grain drying or irrigation. Whole farm organization is a continuation of what farm management and production economists have done for a long time, but with a new dimension. Work under structure emphasizes management problems associated with different types of farms under changed energy conditions and the implications of higher priced or rationed energy on farms by size, type, and control.

Important considerations in energy modeling are (*a*) the time frame that is specified, (*b*) linkages to other units of the food-fiber system, (*c*) appropriateness of energy scenarios, (*d*) the multidisciplinary nature of many problems, (*e*) use flow of energy by form where possible, (*f*) fit in energy production options where it is logical, (*g*) incorporate uncertainty as feasible, and (*h*) do not overlook the management complexity of the options evaluated or included in the analysis.

There was strong agreement on need for greater cooperation and interaction of agricultural economists and scientists of other disciplines. The agricultural engineers, in particular, have been doing useful basic work in technology assessment and energy flows. Among gaps the agricultural engineers see in agricultural economics research are (*a*) not keeping up with current technology, (*b*) overemphasis on Btu accounting to the exclusion of energy form, and (*c*) tendency to ignore weather data and weather-related factors like good field working days.

Optimization of Simulation Models. James N. Trapp, chairperson (Oklahoma State University), Oscar R. Burt (Montana State University), Daryll E. Ray (Oklahoma State University), and C. Robert Taylor and James W. Richardson (Texas A&M University)

The symposium presented and discussed the experiences of five researchers using optimization methods in conjunction with simulation models. The purpose of the symposium was to (*a*) familiarize those in attendance with the concept and nature of optimization procedures that can be used to optimize simulation models, (*b*) review the experiences of the participants in using such procedures, and (*c*) contrast the appropriateness of such procedures to other methodologies.

Trapp characterized the nature of simulation models and noted that their informal structure necessitates numerical rather than mathematical optimization. He outlined the conceptual basis of two nonlinear numerical optimization methods, gradient search and direct search. Taylor commented upon his applications of gradient search procedures to several simulation models including a pesticide management model and a grain stocks model. Richardson reviewed his experiences using a direct search procedure in conjunction with a macroagricultural policy model. Ray discussed the need to match the optimization algorithm with the structural simulation model rather than constructing a simulation model that satisfies the requirements of a particular optimization methodology. Burt contrasted dynamic programming with nonlinear optimization and discussed the use of dynamic programming in stochastic models.

The Role of the Agricultural Economist. D. L. Debertin, chairperson (University of Kentucky), John M. Huie and Rodney L. Clouser (Indiana State Budget Agency), Richard L. Barrows (University of Wisconsin), Glenn Nelson (University of Minnesota), Fred C. White (University of Georgia), George McDowell (University of Massachusetts), and George Goldman (University of California-Berkeley)

This organized symposium discussed the role of agricultural economists working with state and local government decision makers from three perspectives: (*a*) state government personnel, (*b*) research, and (*c*) extension. Huie and Clouser argued strongly for an approach in dealing with state and local government workers in which issues are resolved by the agricultural economist specifying alternative solutions to problems and probable consequences of each alternative. Barrows felt strongly that an advocacy approach was not an effective way to deal with decision makers.

Nelson argued that agricultural economists should take a more active role in determining what ought to be with respect to public decision making and not to adopt goals that are always consistent with those who have economic and political power. He felt that researchers have an obligation to include recommendations while making clear the researchers' underlying values. These views were largely supported by White.

McDowell and Goldman stressed the difficulties in understanding and measuring a community welfare function. McDowell noted that decision mak-

ing within communities necessarily leads to conflicts among various groups affected by the decision. Agricultural economists need to recognize that the political process that leads to the resolution of these conflicts is usually not irrational or unpredictable.

Distribution Impacts of Agricultural Policies: Conceptual Framework and Data Needs. David Harrington, chairperson (ESCS USDA), Don McClatchy (Agriculture Canada), and Mike Boehlje (Iowa State University)

Issues related to the distributional impacts of agricultural policies have been given increased attention. It is becoming more evident that policies affect farms and related households with different characteristics in different ways. Consequently, questions about the adequacy and relevancy of already-available data have emerged.

Speakers pointed to: (*a*) the need for income and wealth data related to households as well as farming establishments; (*b*) advantages of clearly identifying the agricultural sector and the need to develop specific accounts that take into account inflationary conditions of the economy; (*c*) costs and difficulties of obtaining reliable data on variables that indicate income, assets, and wealth; and the (*d*) experience that access to farm taxfile data and linkages of this and census data over time have, in Canada, permitted progress in answering similar questions.

Discussion by participants emphasized problems of respondent burden, the need for priorities, and the need to examine alternative sources of data such as farm records and general surveys.

Food Demand Estimation: Issues and Alternatives. Robert Raunikar, chairperson (University of Georgia), Robert E. Branson (Texas A&M University), Karen J. Morgan (Michigan State University), Daniel S. Tilley (University of Florida), and Joseph Havlicek, Jr. (Virginia Polytechnic Institute and State University)

The symposium represented discussions on data, nutrition, and estimation procedures as they relate to food demand and consumption behavior. Increased attention on food demand and consumption behavior research by a southern regional technical committee with representatives from fifteen states including seven states outside the southern region provided the impetus for the discussions.

Branson discussed existing data sources and their characteristics. He focused on two new developments in data generation; namely, (*a*) the BLS continuing quarterly consumer expenditure survey and (*b*) food store scanner data.

Morgan focused on the opportunities for relating economics and nutrition and the need for a basic understanding of nutrition by researchers. Index nutrients and nutrient density were emphasized as excellent tools in applied nutrition research. She called for economics and nutrition to unite and contribute to food and nutrition policy formulation.

Tilley discussed partial demand systems, emphasizing the vertical market structure and a single level in the marketing channel. He pointed to the need for a theoretical treatment of several commodities within the vertical system.

Havlicek commented on complete demand systems, their theoretical foundations, stages of development, and estimation problems. Further progress would include incorporating noneconomic variables and estimation of linear and nonlinear dynamic systems.

A publication on food demand and consumption behavior is being prepared under the leadership of the symposium participants.

Investment Opportunities for Development Resources in the Less Developed Countries. John W. Mellor, chairperson (International Food Policy Research Institute), T. W. Schultz (University of Chicago), Dave Seckler (Colorado State University), D. W. Thomas (Purdue University), and Vernon Ruttan (University of Minnesota)

The symposium dealt broadly with the role of foreign assistance in the development processes of third world countries. Particular attention was given to Schultz's views on peasant agriculture, the role of incentives and distortions of markets, and the role of human capital in development including the particular contribution of the developed countries in facilitating human capital formation. These issues were found to interact importantly with the increasingly apparent conflict between current emphasis in the foreign aid donor community on direct action to reduce absolute poverty and measures to increase food production, thereby reducing poverty indirectly. There was general agreement on peasant-farmer rationality, the important positive role of production incentives, and the deleterious effect of price distortions. Conflict in the short run between broad-based human capital development through nonformal education and higher education to provide technical or administrative leadership was noted. Note was also made of the comparative advantages of the United States in building agricultural research, of the large role of the Consultative Group on International Agriculture Research and the complementarity of that group with the efforts of the land grant system. Both the panel and the audience expressed widespread dissatisfaction with current foreign assistance emphasis on programs that have proved to be ineffective, both in reducing poverty and in achieving growth, with some sharp dissent from the view that such programs have in fact been ineffective. Much of the session was devoted to interplay between the audience and the panel.

Survey of Annual Outlook Information: 1980. Richard K. Perrin, chairperson (North Carolina State University), Stanley Johnson (University of Missouri), Dean Chen (Wharton EFA), John Ikerd (Oklahoma State University), and Gene Nelson (Oregon State University)

The symposium was organized around the results of the third survey of AAEA members' forecasts of agricultural prices and production. A summary of the results was presented by John Ikerd. There appeared to be no consistent forecast differences associated with the respondents' institutional affiliation or outlook responsibility. Johnson and Chen each presented views on the value of composite forecasts based on weighted averages of forecasts from a number of sources. Nelson presented an analysis of responses to the previous two surveys, examining the frequency distributions of forecast errors by forecaster and by crop. Nelson also raised issues regarding the role of the survey and how it should be conducted in the future, if at all. After vigorous discussion, the task force members agreed to make recommendations regarding this to submit to the economic statistics committee and the president of the Association.

Marketing Alternatives—Direct Marketing with Emphasis on Extension Programs. Ed Watkins, chairperson (SEA-Extension USDA), R. Brian How (Cornell University), Hal Linstrom (ESCS USDA), and J. Hugh Winn (Colorado State University)

ESCS USDA now has available results of a six-state survey (Agr. Info. Bull. No. 436) which provides the first organized data on direct farm sales and products sold. Seventeen additional states have been or are now being surveyed; these results should be available in 1981. ESCS has contracted with states for case studies which will detail farmer direct-marketing costs and margins as they sell to consumers through roadside markets, pick-your-own, and community-based farmers' markets.

Extension programs have successfully featured statewide conferences for farmers who sell direct. These statewide conferences provide a nucleus around which farmers can efficiently and productively learn about direct marketing. Several states use newsletters for updating both farmers and consumers. Information is also provided to consumers through mass media, hot lines, 800 numbers, and directories about what, where, and when products are available. Direct marketing associations can provide farmers with support, information, and a "clearing house" type of action. States also are developing computerized mailing lists and directions that may be quickly, economically, and easily updated.

At the macrolevel, direct marketing likely will remain a small part of our food system. Direct marketing at the microlevel provides increased income opportunities for thousands of full and part-time farmers who are largely excluded from our increasingly concentrated food distribution system.

Priorities in Agricultural Economics: Teaching, Research, Extension. G. Edward Schuh, chairperson (University of Minnesota), Kenneth R. Farrell (ESCS USDA), James F. Tammen, Vernon W. Ruttan (University of Minnesota), Paul W. Barkley (Cornell University), James Bonnen (Michigan State University), Bobby R. Eddleman (Mississippi State University), and Richard A. King (North Carolina State University)

The questions addressed at this symposium had to do with (*a*) whether the Association should take a more active role in establishing priorities; (*b*) if so, how it should do it; (*c*) ideas on the scope of priorities. Participants reviewed the experience of other professional associations in establishing priorities. It was agreed that the search for priorities should come from the members of the Association, and not be imposed from above. The importance of establishing linkages with other professional associations also was stressed.

Some speakers called attention to the rapid change in institutional relationships at the federal level. The point was made that priorities are established at the federal level; the question is whether the Association and its members will be a part of the process. Reference was made to the inhibitions to creativity which formal priorities can bring. It also was noted that articulating a set of priorities is not sufficient to assure funding. It is what the profession produces that matters. Moreover, a major intellectual effort is required if such an effort is to be worthwhile. The consensus of those participating in the session was that a systematic effort to identify priorities and to strengthen funding for agricultural economics programs should be attempted.

Retail Food Price Reporting: Why and Why Not? Daniel Padberg, chairperson (University of Illinois), Robert D. Boynton (Purdue University), Tim Hammonds (Food Marketing Institute), Rod Leonard (Community Nutrition Institute), and William T. Manley (AMS USDA)

Boynton presented an overview of the recently completed Purdue/USDA food price-reporting experiment. A full factorial, longitudinal, matched city design (four city pairs) was employed to assess the impact of price reporting on price levels and dispersion. A modified Solomon-Four group design was used in obtaining survey data on changes in consumers' behavior due to the price report. Results of the six-month experiment indicate that (*a*) relative store price levels dropped in all four test cities during the reporting period, although the magnitude varied among cities from 0.2% to 3.7%; (*b*) prices rebounded strongly following the reports' termination; (*c*) the effect of information on price dispersion was inconsistent, (*d*) consumers' per-

ceptions of low- and high-priced stores changed but patronage patterns did not; and (*e*) price saliency did not increase among respondents.

Hammonds stated that price is ranked only fourth or fifth by food shoppers in most surveys and, therefore, it is improper to overemphasize this choice criterion through a price report. Because previous research suggests that store ranks differ by income class, a price report must incorporate several different marketbaskets. Hammonds felt that the Purdue/USDA results suggest little consumer support of such projects. The full price level declines were not sustainable according to the FMI representative. In addition, the difficulty of assuring accuracy in price reporting challenges its practicality.

The consumers' view of price reporting was expressed by Leonard. He chided the trade for the form and substance of their opposition to the Purdue/USDA study. The key to successful consumer information programs lies in strong community support from the earliest stages of such a project (which he said the Purdue/USDA study did not have).

The inherent desirability of buyer information in enhancing competition seems clear to Manley. He expressed the need for additional work in formulating the appropriate methodology for the complex job of food price reporting.

Some Concerns and Needs in Assisting Farmers to Use Computer Technology. Buel Lanpher, chairperson (SEA-Extension USDA), Steve Harsh (Michigan State University), George Greaser (University of Arkansas), and Harlan Hughes (University of Wyoming)

We are becoming increasingly aware of the advantages for exchanging materials and ideas in the computer area, including better utilization of our scarce resources and the hybridization of ideas and concepts that take place with interaction among professionals. There are several means by which an exchange can occur, including the sharing of computer source code and modeling concepts, supporting educational materials, and implementation experiences. Other alternatives include the multistate development of software and accessing software on other states' computer systems. For farmers who are interested in acquiring microcomputers, it is important to determine how they expect to use them before looking at the hardware, software, and communications aspects. Several key hardware characteristics should be carefully analyzed, such as: memory size, operating systems, and output mechanisms. A limited amount of agricultural software is available and it should be developed to run on a common operating system. The computer should be able to communicate with a host system to enable a two-way transfer of data and software. For transferring data, a producer can use his microcomputer to: (*a*) retrieve current market prices, (*b*) obtain current outlook and situation reports, (*c*) see who has hay or other items for sale, (*d*) retrieve timely news releases, (*e*) send and receive electronic mail, and (*f*) transmit drought conditions or other emergency agricultural information. Information networking directly to producers may well prove to be more valuable than the more traditional problem-solving applications.

Contributed Papers

Risk (Lindon J. Robison, Michigan State University, Chairperson)

"Utilization of an E-L Frontier to Evaluate Differences in Risk Preferences between Large and Small Farm Operators." W. Arden Colette and Steven P. Hubbard (University of Florida)
Field corn production practices typical of large and small farm operations are used to indicate revealed risk preference. On the basis of expected return and variance of returns, differences in attitudes and preferences are indicated. However, at the enterprise level risk preference characteristics in both groups are similar.

"Factors Affecting Farmers' Risk-Income Preferences." George F. Patrick, Suzanne H. Whitaker, and Brian F. Blake (Purdue University)
Risk-income preferences are derived for ninety-one central Indiana farmers using magnitude estimation. Variability-income and bankruptcy-income measures developed are related to socioeconomic variables. Wealth and education have limited effects compared with off-farm employment, percentage debt, and expected levels of income, percentage debt, and net worth growth.

"E,V Frontier Analysis Using Total and Random Variance as Measures of Risk." Boris E. Bravo-Ureta and Glenn A. Helmers (University of Nebraska)
A comparison is made of E,V frontiers using total and random (variate difference) variance for crop production for two counties in Nebraska. In one situation there is a marked difference between frontiers, with random E,V showing less risk for given income levels. In the second case, only a minor difference occurs.

"Risk-Taking Preferences of Farmers in Northern Thailand–Measurement and Implications." William Grisley (Pennsylvania State University) and Earl D. Kellogg (University of Illinois)
Risk-taking preferences were elicited from farmers in Northern Thailand to test the hypothesis of increasing partial risk aversion, quantify absolute risk aversion indexes, and determine if socioeconomic characteristics were associated with risk preferences. An actual pay-off experimental method was developed and utilized to elicit risk preferences.

Marketing–Futures Market (Alden C. Manchester, ESCS USDA, Chairperson)

"Beef Price-Hedging Opportunities for Food Service Institutions." Stephen E. Miller (Clemson University)
This paper evaluates the usefulness of fed cattle futures as a cross-hedging medium for selected wholesale beef prices. Minimum risk cross-hedging strategies generally reduce the variability of steer hinds, boneless beef, and top sirloin butt purchase prices without increasing the mean levels of those prices.

"Commodity Options as an Alternative to Hedging Live Cattle." Lowell B. Catlett (New Mexico State University) and Michael Boehlje (Iowa State University)
This paper examines whether commodity options are viable substitutes for traditional futures hedges for live cattle. Selected strategies for futures and option hedges were simulated with gross mean returns, variance, risk premiums, and risk differentials reported. Results show that options can be used as a hedging substitute.

"Does Hedging Increase Credit for Illinois Crop Farmers?" Kim S. Harris and C. B. Baker (University of Illinois)
Survey responses of lenders in east central Illinois suggest more credit for crop farmers who hedge than for those who do not, but the increment is less than the commitment required to finance margin maintenance. Differences by type and size of lender were not significant, though this conclusion may be limited by nonresponse bias.

"Should Futures Contracts Be Settled by Cash Payments?" Allen B. Paul (ESCS USDA)
The dispersal of cash markets for agricultural products tends to make it difficult to operate some futures markets without recurrent squeezes. Cash settlements, under some circumstances, may alleviate the problem but, as revealed by a recent case study, the mechanism must transcend deficiencies in cash as well as futures markets.

Farm Management (James C. Wade, University of Arizona, Chairperson)

"Economics of Wheat-Fallow Systems." Roger G. Johnson and Mir. B. Ali (North Dakota State University)
Income and risk aspects of wheat-fallow-cropping systems in western North Dakota are analyzed. Yields and prices giving equivalent returns for fallow and nonfallow systems are developed. Results indicate summer fallow is economical at low yields, low wheat prices, and high nitrogen prices. Income variability is reduced using summer fallow.

"Guidelines for Making Commercial Wheat Storage Decisions." James N. Trapp (Oklahoma State University)
Wheat storage profit potential was estimated to be highest when the supply/demand ratio for wheat is

low and stocks are declining. Specifically, supply/demand ratios less than 1.5 imply positive returns and each one million bushel decline in stocks, *ceteris paribus*, increases the rate of return by .05%.

"Weed Control Strategies under Uncertainty." R. P. King, D. W. Lybecker, E. E. Schweizer, and R. L. Zimdahl (Colorado State University)
Continuous corn weed control strategies under uncertainty are analyzed. The analytical model considers both flexible and fixed strategies and intertemporal relationships. At current prices annual herbicide use is optimal. At higher herbicide prices, alternate year herbicide use is optimal. The framework is applicable to a wide range of pest problems.

"Investment, Energy, and Labor Trade-Offs in Swine Production." James B. Kliebenstein and Stephen A. McWilliams (University of Missouri)
This study evaluates how energy and labor costs, and investment levels affect the investment feasibility of pasture, partial confinement, and total confinement swine production facilities. The pasture system provided the lowest present value of investment, labor, and energy costs for most energy-labor cost combinations studied. It was followed by partial confinement and then total confinement. System break-even feed efficiencies and labor costs were also calculated.

Agricultural Policy (Philip Warnken, University of Missouri, Chairperson)

"Price Implications of Farmers' Response to the Farmer-Owned Reserve Program." William H. Meyers and Robert W. Jolly (Iowa State University)
Firm level decision models are developed by viewing the farmer-owned reserve as an investment which is evaluated by means of stochastic efficiency criteria. Aggregate relationships for reserve placements and redemption are derived from the firm level models, and the implications for price level and stability are analyzed.

"An Analysis of the Extension of the Food and Agricultural Consumer Protection Act of 1973." Robert Green (NED USDA), Harry Baumes, Jr. (Virginia Polytechnic Institute and State University), James Johnson and Harlan Burnstein (NED USDA)
The 1973 and 1977 Farm Bills are two legislative acts specifying guides for agricultural policy. The major differences between the two acts and the consequences are discussed. An analysis of an assumed extension of the 1973 Act in lieu of the 1977 Farm Bill is presented.

"Food and Agricultural Act of 1977: Implications for Commodity Research." Maury E. Bredahl (University of Missouri), William H. Meyers (Iowa State University), and Abner W. Womack (University of Missouri)
The provisions of the Food and Agricultural Act of 1977 are briefly reviewed. The implications of the farmer-owned reserve program are discussed. A graphical and mathematical representation of aggregate demand based on the farmer-owned reserve and government-owned stocks is presented. This model is used to identify commodity research areas necessary to the economic modeling of the 1977 Act.

Developing Country Analysis (David E. Kunkel, FAS USDA, Chairperson)

"Progress with Lower Yields: The Case of Early Maturing Corn in West Africa." Hendrik C. Knipscheer (International Institute of Tropical Agriculture, Nigeria)
Early maturing corn varieties are bound to yield less than four-month varieties if grown under optimal growing conditions. The question is whether there is a loss under practical conditions and if so, whether the early maturity of the variety can compensate for the yield reduction. A series of on-farm trials and a simultaneous survey among corn growers were conducted in West Africa.

"Understanding, Quantification, and Modelling in Farming Systems Research: Results of a Simulation Study in Northern Nigeria." Eric W. Crawford (Michigan State University)
The paper discusses understanding versus quantification in farming systems research. The strengths and weaknesses of a large-scale and rapid exploratory surveys are compared. The value of a comprehensive rather than partial approach is illustrated with results from a recent simulation study of farm households in northern Nigeria.

"Food Aid and Induced Technical Change." Gary W. Williams (IED ESCS USDA) and G. Edward Schuh (University of Minnesota)
An analytical argument based on the induced technical change theory is presented in which, given adequate research and diffusion capability, food aid assumes the role of an inducer of technical change and increased agricultural production in the recipient country while facilitating a transfer of resources out of its agricultural sector.

"The Computer: An Appropriate Technology for Managing a Viable Agricultural Credit System in a Low Income Country–Upper Volta." Thomas Stickley (Michigan State University)
A computerized system for managing a viable agricultural credit system in a low income country—Upper Volta—was chosen over alternative labor-intensive methods to gain speed, accuracy, and regularity in production of the statistical reports, aids to field extension/credit staff, and calculation of commissions for loans collected.

Consumer Demands and Retail/Farm Price Spreads (Joseph E. Williams, Oklahoma State University, Chairperson)

"Economic Implications of Changing Household Away-From-Home and At-Home Food Expenditure Patterns." Stanley M. Fletcher (University of Georgia Agricultural Experiment Station)
Viewing a household as a producing and consuming unit suggests a household production model as a viable alternative in explaining a household's life cycle food expenditure patterns. The 1972–73 BLS Consumer Expenditure Diary Survey was used as the data base to empirically investigate a household's away-from-home and at-home food consumption across a life cycle.

"Impact of the Food Stamp Program versus Cash Transfers on the Aggregate Demand for Food: A Theoretical Perspective." Kathryn Phillips (Washington State University)
Comparative analysis of food demand expansion effects of a cash program, as compared to food stamp program, is important for measuring tradeoffs between goals of raising farm income and improving nutritional status of the poor. This paper presents a theoretical basis for assessing food demand impacts under each program.

"National and Regional Household Demands for Meats and Seafood in the U.S.: A Complete Systems Approach." Oral Capps, Jr. and Joseph Havlicek, Jr. (Virginia Polytechnic Institute and State University)
A complete systems approach is employed to identify and evaluate the factors which affect the at-home consumption of meats and seafood in the United States. Brown and Heien's S_1-branch systems is estimated using a full information maximum likelihood algorithm. The source of data is the 1972–73 BLS Consumer Expenditure Survey.

"An Analysis of Short-Run Changes in the Farm-Retail Price Spread for Beef." Michael K. Wohlgenant (North Carolina State University)
A static econometric model of the U.S. beef market was estimated and used to analyze monthly changes in the farm-retail price during the period January 1978 to June 1979. The results indicate that approximately one-third of the increase in the margin may be attributed to systematic changes in the predetermined variables of the model.

Regional Analysis (Fred K. Hines, ESCS USDA, Chairperson)

"Effects of Community Attributes on Total Employment Change in Nonmetropolitan Counties." William Gillis (University of Wisconsin) and Shahin Shahidsaless (University of Mottahedin, Iran)
Specific community attributes such as size and composition of the labor force, personal characteristics of local residents, geographic location, and area population are usually ignored in economic impact studies pertaining to nonmetropolitan areas. This paper demonstrates how specific community attributes influence the total employment impact resulting from an exogenous employment change.

"Distributional Consequences of Consolidated Community Service Provision." Webb M. Smathers Jr., Josef M. Broder, and John F. Porter (University of Georgia)
Cost-minimization decision criteria used to evaluate alternative community service delivery systems often ignore distributional incidence of public good provision and quality of service. Using public choice theory, relationships among transaction costs, political unit size, service quality, and interest group conflict are examined for a case study.

"Retail Sales Migration in the Midwestern United States." Kenneth E. Stone and James C. McConnon Jr. (Iowa State University)
Retail sales migration was traced for all counties in Iowa, Kansas, Missouri, and Nebraska from 1958 through 1977. Rural areas have been experiencing leakages while metropolitan areas have gained. Impacts on consumers include inconvenience and increased energy costs. Impacts on communities, including new and existing businesses, are discussed.

"The Spatial and Temporal Economic Impact of a Nuclear Energy Center—A Methodological Discourse and Application to a Southern Regional Site." Mark S. Henry (Clemson University)
A nuclear energy center site in South Carolina consisting of twelve 1,200 megawatt nuclear plants clustered in a single location is the subject of an economic-demographic impact analysis. A regional input-output model and gravity model are employed to make the analysis. A procedure is developed to allocate the employment, population, and income impact to the CCD level within the impact region.

Resource Economics: Water (Donald J. Epp, Pennsylvania State University, Chairperson)

"Evaluating the Costs of Alternative Water Quality Policies: Effluent Charges or Direct Controls?" Robert A. Solove (Chicago Board of Trade), Gary D. Lynne and Thomas H. Spreen (University of Florida)
Estimates are provided of the costs of water quality improvements to agricultural producers in Florida. Cost was lower with a charge system than with direct controls. This finding is in contrast to that of Jacobs and Casler and the theoretical arguments of Buchanan and Tullock. The key factor is flexibility.

"The Economic Value of Groundwater Recharge for Irrigation Use." Raymond J. Supalla and Dorothy A. Comer (University of Nebraska)
A conceptual model is developed to evaluate the economic benefits from groundwater recharge under conditions where the major water use is irrigation. Both pumping cost savings and aquifer extension benefits are considered. This model is then

applied to a Nebraska case where it was found that recharge benefits vary from less than $2 to nearly $20 as a function of aquifer response, the discount rate, commodity prices, and energy prices.

"Sediment Deposits in Drainage Ditches: A Cropland Externality." Girmai Ibrahim and D. Lynn Forster (Ohio State University)
One of the externalities of soil loss from cropland is sediment deposits. Costs are incurred in sediment removal, and estimates of these costs are made. Also, sediment deposits are found to be significantly related to gross soil erosion estimates from the Universal Soil Loss Equation, an environmental parameter commonly used in economic analyses.

"In Search of the Best Solution for Nonpoint Pollution: Effluent Taxes or Cost-Share Subsidies?" David John Walker (University of Idaho) and John F. Timmons (Iowa State University)
An empirical analysis compared the theoretically more efficient effluent tax with commonly used subsidies and with regulatory policies for reducing agricultural sedimentation in an Iowa river basin. The criteria used in comparing the policies were social cost, equity, administrative cost, political acceptability, and cost to farmers.

Marketing (Jean D. Kinsey, University of Minnesota, Chairperson)

"Food Distributor Procurement Practices: Some Implications for Food Price Policy." Larry G. Hamm (ESCS USDA)
With continued food price inflation, understanding the dynamics of grocery pricing is becoming a policy and research imperative. Retailers buy branded grocery items within the context of extensive standard manufacturer designed promotion programs. The interactions of buyer conduct and manufacturer promotions will, in the absence of local retail market competition, result in higher average food prices. This finding is consistent with recent structure-performance studies and demonstrates the value of including behavioral analyses in studies of U.S. food system performance.

"Price, Quality, and the Brand Image: Evidence from Consumers' Union." W. H. Lesser and R. T. Masson (Cornell University)
The brand image is sometimes seen as providing search reducing signals and enhancing competition. This paper proposes a counter theory for complex products infrequently discussed. Evidence from Consumer Reports supports this hypothesis and allows estimation of overcharges of 5% to 32% over identical nonbranded products.

"The Food Stamp Program's Impact on Low Income Households Food Expenditure Behavior." Larry E. Salathe (ESCS USDA)
Food Stamp Program participants spend on average 10% more on food—19% more on food at home, but 36% less on food away from home than similar nonparticipants. Participation in the program especially increases expenditures on cereal products, nonalcoholic beverages, pork, and processed vegetables.

"Assessment of the Price Impact of the South Carolina Cucumber Market Order." Gary J. Wells and Jerold F. Pittman (Clemson University)
In 1970 a cucumber marketing order was formed in South Carolina. The price impacting provisions of the order appear to be the most effective provisions. Empirical evidence suggests that as a result of the order formation, cucumber prices have increased while price variability relative to the average price has declined.

Farming Systems Analysis (Klaus F. Alt, ESCS USDA, Chairperson)

"Economic Impacts of Restrictions on Selected Soybean Insecticides: An Analysis of a Typical Indiana Farm." Marshall A. Martin, Christopher M. Cashman, and Bruce A. McCarl (Purdue University)
This study analyzed the farm-level economic consequences of possible restrictions by the Environmental Protection Agency on the use of three soybean insecticides commonly applied in Indiana. The empirical results indicate that improved insect control increases yields and income. The benefit-cost ratio for each insecticide was greater than two.

"Determination of the Economic Threshold for Control of Horn Flies on Beef Cattle: A Whole Farm Approach." Daniel V. Gordon and Kurt K. Klein (Agriculture Canada)
Horn fly attacks on beef cattle result in reduced gains on pasture. A whole farm approach was used to determine the economic threshold of horn fly control under various prices of output and cost of control. Six control strategies were evaluated; complete control (four-spray applications) had highest returns but may not be optimal for all farms.

"Farm and Off-Farm Labor: A Cross-Sectional Analysis of Iowa Farm Households." Mark D. Lange (St. Cloud State University) and Wallace E. Huffman (Iowa State University)
This paper presents an economic analysis of the time allocated to farm work and to off-farm by husbands and wives of Iowa farm families. Our econometric results show that husbands and wives allocate their time based upon income, wage, family size and composition, and size of farm considerations.

"The Economics of Organic Agriculture: Does Climate Make a Difference?" E. Canler and W. Arden Colette (University of Florida)
Previous studies have favorably compared organic with conventional production techniques, but have not considered climatic impacts on organic crop

response. Organic vegetable production is analyzed under rigorous climatic conditions in Florida. Cost per output unit is higher for organic crops. Labor-intensive organic production is commercially infeasible in the study area.

Natural Resources—Policy Applications (Ivery D. Clifton, University of Georgia, Chairperson)

"Trade-Offs between Agricultural and Urban Nonpoint Pollution Control." William M. Park (University of Tennessee) and Leonard A. Shabman (Virginia Polytechnic Institute and State University)
The relative cost effectiveness of agricultural and urban BMPs is investigated for the Occoquan River Basin in the Washington, D.C., metropolitan 208 area. Implications of agricultural BMPs being more cost effective than urban BMPs on acceptance and implementation of economically efficient nonpoint pollution control strategies are discussed.

"Assessing the Impact of Peak-Load Electricity Pricing and Solar Tax Credits on the Adoption of Solar Energy." Robert J. Procter and Wallace E. Tyner (Michigan State University)
A simulation model was developed to estimate the life-cycle costs of residential heat-pump, resistance, and active solar heating systems. Using Indianapolis, Indiana, as a case study, our results indicate that a move to peak-load electricity pricing can adversely affect any incentive for adopting solar energy provided by solar tax credits.

"The Impact of Tax Policy on Soil Conservation." Bruce Johnson and Maurice Baker (University of Nebraska)
Direct and indirect tax impacts on soil conservation objectives are mixed. Conservation expenditure deductions, cost-share exclusions, and use-value assessment can provide conservation incentives but real estate prices fueled by tax deductions are disincentives. Production practices are unresponsive to property taxes; thus, they are neutral toward conservation incentives.

"A Self-Financing Farmland Preservation Program." Charles A. Sargent (Purdue University)
A farmland preservation program is proposed that combines current growth management approaches with a transfer fee plan. Agricultural zoning, fees assessed on land sold for development, plus cash benefits, would create a combination of "sticks" and "carrots" to encourage preservation. Costs and benefits are analyzed and a hypothetical example is given.

Estimation of Demand (David Kelch, ESCS USDA, Chairperson)

"Incorporating Technological Change in Economic Relationships: An Application to the Demand for Formula Feed in France." Yves Surry and Karl D. Meilke (University of Guelph)
The use of a linear time trend as a proxy for technological change in economic relationships often leads to unsatisfactory econometric results. An alternative procedure based on variational parameter procedures is proposed and applied to the demand for formula feed, fed to hogs, in France. The need to incorporate the technological diffusion process provides the theoretical justification for the procedures used, while the empirical results are quite encouraging.

"Estimation of Demand Parameters Based on Factor Analysis." Chung-Liang Huang, Robert Raunikar, and Stanley M. Fletcher (University of Georgia, Experiment)
A regression equation is derived from factor analysis. U.S. regional demands for at-home consumption of ground beef are estimated for the 1972–73 BLS Consumer Expenditure Diary Survey. Empirical results suggest that factor analysis is a viable alternative to conventional OLS procedure when there is error in the variables.

"Discriminating among Alternative Changing Taste Demand Models." Richard D. Green (University of California-Davis), Rulon D. Pope (Texas A&M University), and Tim T. Phipps (University of California-Davis)
Economists have been concerned about the best way to model changes in taste in demand analyses. Recently non-nested testing procedures have been devised that, when applied to demand analyses, allow one to discriminate among the various changing taste specifications. Results from this paper address some of these interesting questions that economists in the past have not been able to treat in a rigorous fashion.

"Milk in the Fast-Food Outlet: Consumer Demand and Marketing Outlook." Kathy E. Gill and Joel S. Williams (Virginia Polytechnic Institute and State University)
Consumer demand for milk in Virginia fast-food outlets proved very elastic, −3.035. Milk consumed away from home appears to be a different good than milk consumed at home. The cross-price elasticity with soft drinks was also elastic, 4.075. The dairy industry should avoid price war with the soft-drink industry.

Value of Information (Josef M. Broder, University of Georgia, Chairperson)

"The Economic Value of Genetic Information in Selecting Sires." Richard K. Perrin (North Carolina State University)
Contributions by economists to the understanding of the genetic selection choice are reviewed. Concepts for determining the expected value of sire test information are then developed and applied to cen-

tral boar testing stations. For a producer choosing between a tested and an untested boar, the test information is estimated to have a value of about $160, less testing costs.

"The Value of Electronic Marketing—Some Empirical Evidence." D. P. Helmreich, J. E. Epperson, and C. L. Huang (University of Georgia)
Georgia feeder cattle teleauction prices are determined to be significantly greater than sale barn prices in 1979. Enhanced pricing efficiency in cattle marketing is indicated by results of the analysis. Further suggested are improvements in physical efficiency.

"Stochastic Effect of Weather on Crop Production: The Value of Weather Information to Individual Corn Producers." Thomas F. Tice (Oklahoma State University) and Rodney L. Clouser (Indiana State Budget Agency)
Stochastic weather events are critical in determining corn and soybean yields in the Midwest. Discrete stochastic programming techniques incorporate the probability of stochastic weather events in a decision model. By basing production decisions on current weather information and the probability of future weather events, the farmer is capable of increasing farm profitability.

"A Method to Measure the Efficiency of Feeder Cattle Grade Standings." Kim B. Anderson (University of Kentucky) and Alan E. Baquet (Oklahoma State University)
The objective of this paper was to present a methodology for determining the efficiency of a grading system. The methodology was used to compare the efficiency of the 1979 feeder cattle grading system with an alternative grading system. The potential economic gain of implementing the more efficient system was determined.

Societal Benefits from Alternative Activities (Donald F. Scott, North Dakota State University, Chairperson)

"An Economic Analysis of the Intertemporal Monetary Benefits to Coal Land Owners in Eastern Oklahoma." Christopher O. Obiechina, Daniel D. Badger, and Joseph E. Williams (Oklahoma State University)
To identify private from societal benefits/costs in coal development, a linear programming model was used to project the monetary benefits accruing to coal land owners. Using two alternative mineral rights transfer strategies (land trades) to leasing of coal land, it was concluded that private monetary gains to land owners are substantial.

"Use of a Dynamic Optimization to Evaluate a Buffer Stock for Cocoa." Seon Lee (Korea Development Institute) and David Blandford (Cornell University)
Optimal control theory is used to determine optimal buffer stock purchases/sales to stabilize price at systematic trend over the period 1956–76. Although the instability of price and of producer revenue falls and average revenue increases, the degree of market intervention necessary and its costs are substantial.

"Welfare Measures for a Price Distortion in a Multiproduct Multifactor Setting." Glenn S. Collins (Texas A&M University) and Daryll E. Ray (Oklahoma State University)
This paper investigates welfare measures in an economy comprised of vertically related multiproduct and multifactor industries, where a particular market is subject to a price distortion. It is shown that total welfare changes can be obtained with the use only of general equilibrium prices and quantities in the distorted market.

"Impact of Agricultural Export Trade on a State's Economy: The Case of Missouri." Emilio Pagoulatos (University of Florida), Robert Sorenson (University of Missouri-St. Louis), and Angelos Pagoulatos (University of Kentucky)
A methodology based on I-O analysis is developed and utilized to investigate the impact of agricultural and nonagricultural exports on the Missouri economy for 1963 and 1972. Agriculture was found to be by far the most important sector in terms of the impact of its export sales on state economic activity. Agricultural export sales contributed to 29% of state business activity, 34% of personal income, 49% of total state revenues, and about 34% of local taxes in Missouri in 1972.

Grain Transportation (L. D. Schnake, ESCS USDA, Chairperson)

"Estimation of Grain Transportation Demand Using Time-Series Data." William W. Wilson (North Dakota State University)
Peak period problems in grain transportation and the concept of peak-load pricing are addressed in this paper. A three-equation recursive econometric model was specified and estimated for wheat movement from North Dakota to Duluth-Superior. The results indicate that total transportation movements were inelastic with respect to prices received by producers. Elasticities were also derived for modal movements.

"The Impact of Demand-Sensitive Railroad Rates upon the Storage and Transportation System for U.S. Feed Grains." Linwood A. Hoffman (ESCS USDA) and Lowell D. Hill (University of Illinois)
A storage and transportation model of the U.S. feed grain industry was developed to measure the potential impacts of demand-sensitive rail rates. At the national level, a 5% to 15% change in rail rates simultaneously increased rail revenue and traffic

volume and reduced seasonality of rail demand. As a consequence, total system costs increased. Regional results differed slightly.

"Effect of Rural Road Development on Grain Assembly Costs." Jay Dean Tucker and Stanley R. Thompson (Michigan State University)
The possible effect of rural road development policies and selected maintenance programs upon grain marketing and transportation costs in southeastern Michigan is examined through a linear programming algorithm designed to minimize the aggregate transport and handling costs. The model's empirical results indicate a direct relationship between rural road development and maintenance policies and grain transport marketing costs.

"Alternative Export Wheat Distribution Systems for the Southern U.S. Plains." Stephen Fuller (Texas A&M University), Orlo Sorenson (Kansas State University), Marc Johnson (North Carolina State University), and Robert Oehrtman (Oklahoma State University)
This paper reports on alternative logistical systems for marketing export-destined wheat from southern U.S. plains. The study concludes (*a*) the region's export system is not economical when compared to alternatives which include multicar shipments, (*b*) efficiency gains are derived from the unit train concept, and (*c*) feasibility of subterminals and associated unit trains are not contingent upon rail abandonment.

Trade of Agricultural Commodities (Paul V. Johnson, ESCS USDA, Chairperson)

"Impact of Meat Imports on Least Cost U.S. Beef Production." K. E. Nelson (NED ESCS USDA, University of Illinois), N. R. Martin, and G. M. Sullivan (Auburn University), and R. J. Crom (NED ESCS USDA)
A linear programming model of the U.S. beef industry evaluates meat import policies for a least cost optimal beef cow herd. Regional adjustments in cow numbers and corn utilization are examined. Average cost for the United States is estimated for different levels of cow herd size and beef production.

"The Effect of the Suspension of Wheat Sales to the USSR on U.S. Prices and Exports." Alan J. Webb (IED ESCS USDA) and Leo V. Blakley (Oklahoma State University)
A world wheat trade forecasting model is used to compare a sales suspension of maximum effectiveness with a no suspension alternative. United States producer prices are shown to decline $.26 per bushel and exports fall 1.5 million tons in 1980. Increased market stability results from diminished influence of Soviet supply variability.

"A Comparison of the Impact of Alternative Government Policies: The Soviet Union Grain Embargo." Harry S. Baumes, Jr. (Virginia Polytechnic Institute and State University), Abner W. Womack, and Maury E. Bredahl (University of Missouri)
This paper examines alternative policy measures taken by the administration to support grain price in the wake of the Soviet grain embargo. Most notably in the analyses is the fact that exportation of grain has a stronger price impact than entry of grain into the farmer-owned reserves.

"Impact of Japanese Rice and Wheat Policy on Trade." Cathy L. Jabara and William T. Coyle (ESCS USDA)
The interaction of Japanese rice and wheat policy is described and analyzed through estimation of an econometric model. The trade impact of recently announced increases in wheat support prices and diversion payments is simulated. Results indicate the price change will reduce wheat imports, but the imports are not sufficient to balance rice production and consumption.

Production Economics—Specification of Supply Models (Eric Wailes, University of Arkansas, Chairperson)

"Statistical Tests of the Nonreversibility of Agricultural Supply Hypothesis." Mike Woods, Luther Tweeten, Daryll E. Ray, and Greg Parvin (Oklahoma State University)
Aggregate supply equations are estimated using the Wolffram and Houck methods to segment the output price into separate independent variables for increasing and decreasing prices. Null hypotheses of equal price response coefficients for falling and rising prices could not be rejected. The same conclusion was reached using Chow's structural stability tests.

"A Random Parameter Regression Approach to Estimating a North American Pork Supply Model." Bruce L. Dixon (University of Illinois), Larry J. Martin (University of Guelph), and Ellen W. Goddard (Latrobe University, Australia)
Equations modelling pork supply for North America are estimated assuming coefficients change both randomly and systematically. Results show predictive superiority of time varying models over least squares for sample period. *Ex post* forecasting does not exhibit similar superiority. Measuring structural change and effect of additional observations on estimates are considered.

"Estimation of the Supply of a Perennial Using Sparse Data." James W. Dunn and Richard P. Bellock (Pennsylvania State University)
Traditional methods of estimating the supply of perennials require acreage data, yet such data is usually not collected. In this study, a model for the supply of a perennial crop which does not require

acreage data is developed. The model is estimated for asparagus, strawberries, and eggs with satisfactory results.

"On the Use of Price Ratio in Supply Response." Jean-Paul Chavas (Texas A&M University)
Because of a lack of data or multicollinearity problems, it is fairly common to include only a subset of the relevant prices in an econometric model of supply response. This paper provides some evidence on the validity of using price ratios in this situation. A model of the U.S. poultry and egg industry where feed cost and output price are the only economic variables considered suggests that the use of price ratios would be inappropriate. If careful attention is given to model specification, it appears that homogeneity restrictions should not be imposed on supply response models unless the excluded prices are known to have little influence on production decisions.

Empirical Estimation Considerations (Peter H. Greenwood, University of New Hampshire, Chairperson)

"Elasticities and Dynamics: Conceptual Problems in Empirical Measurement." Ralph Semprevio and Kenneth Baum (Virginia Polytechnic Institute and State University)
Although the supply elasticity concept is a useful theoretical and analytical tool, empirical estimates of supply elasticities have not always been recognized as having restricted uses. Dynamic multipliers are not constrained by these restrictions and, therefore, represent more realistic measures of commodity supply response under either multimarket or multiperiod conditions.

"The Policy Relevance of Alternative Elasticity of Substitution Measures." Barry C. Field and P. Geoffrey Allen (University of Massachusetts)
Flexible forms increase the potential difficulties of interpreting and reconciling alternative estimates of the elasticity of substitution (ES). We stress differences between measures based on constant and variable output, provide a general expression for the latter, and suggest the usefulness of measuring short- and long-run ES by modeling input adjustments.

"Specification of the Profit Equation and Expected Profit Maximization." Roger Selley (University of Arizona)
Proper specification of the profit equation where profits are stochastic requires that special care be given to specifying the profit equation so that it is consistent with the characteristics of the profit maximization problem. It is shown here that the relationship of cost curves with the production function is not, in general, the same in the stochastic case as in elementary firm theory. It is also shown that although the "expected product price equals expected marginal cost" rule holds when expected marginal cost is interpreted as the expected marginal cost of planned production, the "expected input price equals expected marginal value product" rule for a planned input requires an adjustment for the increased cost of stochastic inputs.

"The Rational Expectations Hypothesis: An Empirical Application to the Florida Escarole Market." J. Scott Shonkwiler (University of Florida)
Empirical implementation of the rational expectations hypothesis requires that expectations be determined endogenously. Applications of both this methodology and the traditional adaptive expectations procedure to a model of the Florida escarole market are presented. The results suggest that escarole producers are not rational in the sense of Muth's hypothesis.

Commodity Models (David Armstrong, Michigan State University, Chairperson)

"A Quarterly Econometric Forecasting Model of the American Cheese Market." Joe H. Dewbre (Wharton Econometric Forecasting Associates)
This paper describes a quarterly econometric forecasting model of the American cheese subsector that includes equations for cheese production, commercial sales, CCC purchases, market prices, retail prices, and commercial stocks. Dynamic simulation exercises over the sixteen quarters from 1976 to 1979 were used to validate the model. Results of a dairy policy simulation experiment are also given.

"The Soybean Sector in the 1970s: An Analysis of Price Variability." Suchada V. Langley and William H. Meyers (Iowa State University)
Price variability in the 1970s is analyzed for the soybean sector using structural and time series models. The impact of changes in predetermined variables on the price level is analyzed with the structural model. Supply factors, trade factors, and domestic demand factors are evaluated over the period 1971 to 1977.

"Petroleum Prices and the Market for Natural Rubber." Abu Bakar Man and David Blandford (Cornell University)
An annual econometric model that reflects price competition between natural and petroleum-based synthetic rubber is used to project world production, consumption, and prices in 1985. The contribution of increasing petroleum prices to the projected changes in these variables is determined. The results suggest that substantial increases in the real price of natural rubber are likely.

"Market Demand for Residual Stocks and Price Variability: A Case Study of U.S. Wheat." Chung J. Yeh (USDA)
An ordinary least squares technique with dummy variable and several dummy-related variables is used to test changes in wheat demand structures and impacts of residual stocks on prices. Wheat demand structures appear to have changed significantly over time and prices are highly affected by residual stock levels.

International Trade (Patrick O'Brien, ESCS USDA, Chairperson)

"An Analysis of Ocean Freight Rates for Grains with Reference to Port Advantage." James K. Binkley (Purdue University) and Bruce Harrer (Battelle Pacific Northwest Laboratories, Richland, Washington)
Two equations relating ocean grain rates to cost factors are estimated. The major variables examined deal with distance, shipment size, overall shipping activity, and handling costs. The results are used to suggest reasons for rate differences associated with major port areas.

"Demand Elasticities for Soybean Meal in the European Community." Lowell D. Hill (University of Illinois) and Hendrik C. Knipscheer (International Institute of Tropical Agriculture, Nigeria)
An econometric model provided estimates of the effects of EC agricultural policies on their demand for U.S. soybeans. Disaggregating world soybean demand into geographical regions improved elasticity estimates over previous studies with respect to substitutes, own price, and profitability index. EC mills' power surpluses had significant but negative small effect on U.S. soybean exports.

"An Economic Analysis of Welfare Distribution among Trading Countries under Alternative Market Imperfections." Dae H. Song and Milton C. Hallberg (Pennsylvania State University)
A model of international trade that permits market imperfections from either exporters or importers is introduced and a quadratic program to find equilibrium solutions under alternative market structures is formulated. A procedure for the welfare analysis of a wheat exporter's cartel is outlined.

"Price and Income Effects of Devaluation—A Case Study of South Korea." Gene K. Lee (IED ESCS USDA)
An input-output model is used to examine price and income effects of devaluation. The results indicate that when exports are dependent upon imports of intermediate products, domestic output prices will increase significantly. Thus, the results suggest that the net export effect of devaluation is not as great as is usually expected when a country devalues its currency.

Natural Resources—Irrigation (Darrell Hueth, Lawrence Livermore Laboratory, Chairperson)

"Optimal Scheduling of Irrigation by Control Theory: Oklahoma Panhandle." Thomas R. Harris and Harry P. Mapp, Jr. (Oklahoma State University)
Continued irrigated production in the Oklahoma Panhandle is threatened by the declining groundwater supply and increasing fuel costs. A plant growth model and optimal control theory techniques were used to derive irrigation strategies which, when compared with contemporary irrigation practices, reduce water and energy use while maintaining producer net returns.

"Electricity Prices and Irrigation Development Feasibility." Joel R. Hamilton (University of Idaho), Gary S. Barranco (U.S. Forest Service), and David J. Walker (University of Idaho)
A methodology was developed to measure impacts of rising electricity prices on high lift irrigation development. Effects of farm size, crop prices, yields, lift heights, and distance from water source were also incorporated. Results indicate that rising electricity prices will make development infeasible in high elevation areas of southern Idaho.

"Irrigation and the Demand for Electricity." Ruth J. Maddigan, Wen S. Chern, and Colleen A. Gallagher (Oak Ridge National Laboratory)
In order to anticipate the need for generating capacity, utility planners must estimate the future growth in electricity demand. The need for demand forecasts is no less important for the nation's Rural Electric Cooperatives (RECs) than it is for the investor-owned utilities. The RECs serve an historically agrarian region; therefore, the irrigation sector accounts for a significant portion of some of the Cooperative's total demand. This paper develops a model of the RECs' demand for electricity used in irrigation.

"The Derived Demand for Irrigation Scheduling Services." Daniel J. Dudek and Gerald L. Horner (NRED ESCS USDA, University of California-Davis)
Scientific irrigation scheduling is a technique for systematically determining the proper data and quantity of each irrigation in individual fields. This technique is presently being used by government agencies and private companies in the western United States to assist farmers in planning irrigations. This paper presents the results of a case study of the regional economic effects of scheduling in the A and B district in Idaho. The analysis indicated that substantial reductions in total water use resulted from implementation of the service. However, the acreage of scheduled irrigation activity was found to be fairly sensitive to the cost of the service and the cost of irrigation water.

Scale Economies and Income Distribution (Roger G. Johnson, North Dakota State University, Chairperson)

"Scale Economies on Peanut-Rice Farms in Northeast Thailand." Aroon Auansakul (University of Kentucky)
The relative technical and economic efficiency for small and large rice-peanut farm size classes in northeast Thailand are compared. A theoretical model is developed and empirically tested with equal prices for inputs and products. Small farms, while more labor intensive, attain higher levels of both technical and economic efficiencies.

"Barriers to the Expansion of Small Farms." John Ellerman and Lyle Solverson (Southern Illinois University)
The major objective of this study was to identify factors that may act as barriers to the expansion of small farms. The study concludes that there are three types of barriers to expansion: (*a*) those barriers due to small farmers' inability to use existing methods, (*b*) those barriers that are due to small farmers' refusal to use available methods, and (*c*) natural barriers.

"Potential Effect of Small-Farm Technical Assistance Programs on Public-Revenue Accounts." Eldon D. Smith, Harry H. Hall (University of Kentucky), and Don Simon (ESCS USDA)
This paper presents a conceptual model for considering the tradeoffs between technical assistance and public-welfare assistance for impoverished limited resource farmers. The hypothesis is that a combination of technical assistance and welfare assistance will be more cost-effective than welfare assistance alone. For a sample of 120 limited-resource farmers in the Appalachian region of Eastern Kentucky, some on welfare assistance, the potential effect of technical assistance on public-revenue accounts is evaluated.

"Agricultural Pricing Policy and Income Distribution in a Multiobjective Framework: A Dominican Republic Example." Elizabeth B. Erickson (University of Akron) and Robert M. House (OICD USDA)
A large-scale LP model is used to analyze the effect of pricing subsidy alternatives. Results are expressed to reflect performance with respect to government multiple objectives. Trade-offs and complementarities are presented in a form designed to be of assistance to decision makers, using factor analysis and policy frontier functions.

Incorporating Risk in Decision Making (Sidney C. Bell, Auburn University, Chairperson)

"Theoretical Criteria and a Proposed Empirical Method for Computing Historical Risk Measures." Linda S. Calvin (ESCS USDA), Ron C. Mittelhammer and Douglas L. Young (Washington State University)
Suggested criteria for evaluating the appropriateness of historical risk measures are presented. A continuously adjusted weighted moving average (CAWMA) method for calculating historical risk is introduced and compared to past historical risk computation procedures both in terms of the suggested criteria and in the context of specific empirical examples.

"Risk Preferences and Perceptions in the Use of IPM." W. Michael Hanemann (University of California-Berkeley) and Richard L. Farnsworth (ESCS USDA)
The risk preferences, the actual returns, and the subjective probability distributions of returns of a sample of forty-four cotton growers in the San Joaquin Valley are studied; twenty-eight growers use IPM, sixteen use conventional chemical pest controls. The choice of strategy is explained in terms of differences in risk perceptions rather than preferences.

"A Method of Incorporating Risk Management into Extension Programs." Judy Ohannesian, Wesley N. Musser, Fred J. Benson, and Vernon R. Eidman (University of Minnesota)
This paper proposes the use of a lower confidence limit for profits as a method to incorporate risk management into a general extension program. The confidence interval approach is adapted from portfolio analysis. The method is illustrated for a crop enterprise-planning program in Minnesota.

"A MOTAD Risk Analysis of Swine and Competing Farm Enterprises in the Virginia Tidewater Area." Larry Johnson and Kenneth Baum (Virginia Polytechnic Institute and State University)
A MOTAD analysis of the risk and economic impact of three alternative swine enterprises has been evaluated in the Virginia Tidewater region. Although alfalfa hay and corn competed with feeder pig and finishing enterprises at lower income levels, farrow-finish operations were elected at higher income levels.

Marketing Decisions and Price Analysis (Donald E. Farris, Texas A&M University, Chairperson)

"Supply and Demand Considerations of Agribusiness Marketing Portfolios." Steven T. Buccola (Virginia Polytechnic Institute and State University)
Conditions are derived for determining the product volumes which expected utility-maximizing firms would sell or buy under alternative contract arrangements. Supplies and demands under each arrangement are related to contract parameter levels. An application is made to negotiations between farmer and processor concerning terms of fixed-price, forward deliverable contracts.

"The Consumer's Use of Futures." Peter Berck and Stephen G. Cecchetti (University of California-Berkeley)
This paper shows that futures should be included in an efficient portfolio and that the degree of their inclusion depends critically on the evaluation of income in real terms. As planned consumption is balanced toward items traded in the futures market, holdings of futures are shown to increase.

"Causal Relationships in the Fed-Beef Cattle Market." Thomas H. Spreen, J. Scott Shonkwiler, and Julio Chang (University of Florida)
The causal relationships among feeder calf prices, feed cattle prices, and feed costs are investigated using three alternative statistical tests. Employing the Granger concept of causality and using monthly data, it is determined that feed costs lead both animal price series, but no lead-lag relationship is found between feeder steer and Choice steer prices.

Marketing—Structure, Concentration (John M. Connor, ESCS USDA, Chairperson)

"The Commodity Implications of Expansion of Sales of Food-away-from-Home." A. Desmond O'Rourke (Washington State University)
The relative increase in expenditure on food-away-from-home at the expense of the at-home market has been well documented. However, little work has been done on the differential impact of this shift on agricultural producers, processors, and marketers in different locations and faced with different marketing institutions. This paper reports on the changing impact of the away-from-home phenomenon on major commodity groups, processed products, and institutional sales. It appears that the manner in which the away-from-home market has evolved has had significant impact on many commodities, products, and their respective producers and processors.

"Changing Structure of the Fluid Milk-Processing and Distribution System." Richard F. Fallert and Harold W. Lough (ESCS USDA)
The size distribution and firm organizational structure of fluid milk processors under federal milk markets orders is presented for the months of December 1971 and 1977. Forces impacting the industry and bringing about a rapidly changing market structure are presented. Likely future impacts are explored and implications for policy makers and industry decision markers are outlined.

"The Effects of Market Concentration on Urban Food Prices." R. McFall Lamm, Jr. (NED ESCS USDA)
This paper explores the effects of concentration on urban food prices utilizing different measures of market concentration. An econometric model of urban food price determination is developed and estimated using pooled cross-section and time-series data. Results indicate that food prices are higher in markets where concentration is greatest.

"Advertising and Concentration Change in U.S. Food and Tobacco Product Classes, 1958–72." Richard T. Rogers (FMS ESCS USDA, NC-117 Food System Research Group)
There is increasing evidence that advertising plays an especially prominent role in structural change. Herein the author examines the effect advertising has had on changes in concentration in U.S. Food and Tobacco Product Classes. Regression results indicate that television advertising has had a strong positive influence on concentration change.

Application of Quantitative Techniques to Agriculture (Kenneth H. Baum, Virginia Polytechnic Institute and State University, Chairperson)

"A Review of Monte Carlo Applications in Agricultural Research." Leonard E. Burman (University of Minnesota)
Monte Carlo Programming (MCP) is a means of dealing with problems which are too mathematically complex to be treated with deterministic methods (such as QP). Its principal drawback is cost. Methodology and applications are discussed. Promising directions for future research are suggested.

"Use of Cluster Analysis to Identify Size Structure in Irrigated Agriculture." James C. Wade (University of Arizona)
Analysis of structure in American agriculture often overlooks both the subtle and complex differences among farms of varying sizes within a relatively small production area. The resource components of farms of various sizes significantly affect the size and crop mix structure of each group of farms. To examine this structure sample farms have been grouped using cluster analysis. The multivariate data observations are grouped without preconceived hypotheses. Statistical analysis of the results reveals that farms group somewhat by size and crop mix. However, small farms do vary substantially in composition from larger farms and avoid significant production of risk-oriented crops.

"Tests of Exogeneity in Bivariate Regressions: Some Empirical Results for Slaughter Cattle and Hogs." David A. Bessler and Jon A. Brandt (Purdue University)
The paper investigates exogeneity tests between hog prices and sow farrowings and between cattle prices and cattle on feed inventories. The tests, which are useful in constructing dynamic bivariate regressions, suggest that sow farrowings is empirically exogenous with respect to hog price and that cattle price is exogenous with respect to cattle on feed inventories.

Crop Acreage Estimation (John Groenewegen, ESCS USDA, Chairperson)

"A Behavioral Model of Corn Acreage Response under Conditions of Uncertainty." Harlan Burnstein (NED ESCS USDA)
This paper investigates the impact of corn price variability on planted acreage. The results of an economic analysis indicate corn acreage to be inversely related to corn price variation with the negative impact decreasing as the average level of past prices increases.

"Demand for Crop Acreage: A Structural Approach." Lloyd D. Teigen (NED ESCS USDA)
The demand for land as a productive input responds to the price of land relative to the price of the commodities produced by that land and the price of other inputs. Acreage control policies are quantified in terms of the maximum percentage of land which could be diverted from commodity production. This specification is tested using 1967–78 data for wheat, corn, soybeans, oats, and sorghum.

"Policy Control of Corn Acreage: A Re-Examination." Robert D. Weaver and Amy Krainik (Pennsylvania State University)
Parameters of a corn acreage response function estimated for the Corn Belt states are found to be unstable over the three economic regimes established by postwar feed grain programs. Market price elasticities are larger when programs imposed acreage restrictions. Supply elasticities with respect to policy instruments and fertilizer prices are also reported.

"Multiple Crop Supply Component of the World Grains, Oilseeds, and Livestock Model." Karen Liu (IED ESCS USDA)
The purpose of this paper is to resolve conceptual problems in the crop supply component of the present GOL model and to develop the conceptual framework for a multiple-product production system of a multiple-commodity agricultural trade model. The major emphasis on the revision of the crop supply system is structural consistency in order to assure consistent acreage allocation among crops and to impose total arable land area constraints on supply.

Farm Management—Beef (Timothy G. Baker, Purdue University, Chairperson)

"Recycling Paper Mill Wastes as Cattle Feed in Small Livestock Operations." Donald J. Epp and Trond Grenager (Pennsylvania State University)
Recycling paper mill waste "fines" as a livestock feed ingredient reduces feeding costs for small (100 head) operations 31% for cow-calf operations, 35% for stockers, and 28% for feeders. This savings can pay for transporting the fines up to 250 miles and reduces landfill requirements near the paper mill.

"The Inclusion of Beef Cattle in the Optimal Enterprise Organization." J. Walter Prevatt, John E. Reynolds, and Bryan E. Melton (University of Florida)
A profit-maximizing model that included many of the diverse aspects of beef cattle production and interrelationships among beef cattle, forages, and field crops was developed within a dynamic linear programming framework. The optimal resource organization was determined given price levels that existed during 1973–77.

"Economics of Beef Cow Culling and Replacement Decisions under Genetic Progress." Bryan E. Melton (University of Florida)
Beef herd managers alter the genetic composition and thus the profitability of their herds through culling and replacement. Because genetic change is a form of technological progress, a general replacement criterion for assets undergoing either exogenous or endogenous progress is derived. Its application is then illustrated through an empirical example.

"Economic Evaluation of Beef Cow Size and Milking Potential." Kenneth W. Stokes, C. Richard Shumway, Terry C. Nelson, and Tom C. Cartwright (Texas A&M University)
Feeder calf classes (sex, age, and condition) and cull sales are simulated for herds which differ in size and milking potential genotype. Pricing equations, cost, and net returns are calculated for the 1972–78 period. Results indicate higher returns and lower variance associated with increased cow size and decreased milking potential.

Aggregate Analysis (James D. Johnson, ESCS USDA, Chairperson)

"The Rate of Return to Investment in Agriculture and the Measurement of Net Farm Income." Bruce L. Gardner (Texas A&M University) and Bruce Hottel (NED ESCS USDA)
This paper investigates three problem areas in the measurement of returns to agricultural assets. First, measuring returns as a residual creates inevitable choices among alternative procedures, none of which is exactly suitable, and which make a substantial quantitative difference. Second, annual rates of return, even if properly measured, have a quite limited economic meaning. Third, in an inflationary environment, current USDA measurement results in a substantial understatement of net farm income because the inflation premium in interest costs is charged against current income flows.

"A New Look at the Relationship between Farm Real Estate Prices and Expected Returns." Larry D. Hauschen (Federal Land Bank of St. Paul) and William McD. Herr (Southern Illinois University)
This study employs the capitalization approach and the polynomial lag model (Almon lag) to examine the changes in farm real estate prices from 1950

through 1977. The study found that when net returns to real estate are measured more accurately and expectations regarding net income are based on incomes earned in the seven previous years, the capitalization model explains changes in farm real estate values since 1950.

"The Differential Effects of Inflation on Selected Food-Related Sectors of the U.S. Economy, 1967–78." Gerald Schulter (NED ESCS USDA) and Gene K. Lee (IED ESCS USDA)
A consistent economic model for measuring the price-induced income effects of relative price changes is reported and used to analyze sectors within the food system. Since 1972 the farm sector has benefited from relative price changes but export-oriented crop sectors have done better than domestic-oriented crop sectors and livestock.

"Relationships among Households and Farm Establishments in the 1980s: Implications for Data." Lyle Schertz (ESCS USDA)
Data and related research presently available does not provide approximate income and wealth distribution indicators for households that provide resources to farming. These kinds of data are necessary for dealing with structural issues. Such data should be part of the larger system of data related to farm establishments.

Natural Resources—Empirical Estimation Approaches (Tony M. Grano, ESCS USDA, Chairperson)

"Proper Estimation and Specification of Sustained Yield Functions: An Application to Deer Harvesting." Roger Mann, Kenneth Baum (Virginia Polytechnic Institute and State University), and Ronald Shane (University of Nevada)
Correctly specified economic models have not always been utilized for the empirical measurement of sustained yield functions necessary for determining optimum effort allocations for renewable natural resources. In this analysis, empirical sustained yield functions for deer harvesting are successfully estimated with both current and lagged hunter efforts as explanatory variables.

"Estimating Social Values of Sport-Caught Fish: A Suggested Approach." Karl C. Samples (University of Hawaii) and Richard C. Bishop (University of Wisconsin)
A promising new approach to estimating values of sport-caught fish is introduced as a practical alternative to theoretically questionable methods currently in use. An empirical example of application of the proposed approach is provided using results from a multiple-site travel cost study of Lake Michigan fishing.

"Externalities and Joint Supply Response in Outdoor Recreation Research: An Example from Irrigation Development." Scott C. Matulich (Washington State University)
Outdoor recreation research is criticized for failing to evaluate temporal impacts of federal water project development upon recreation resources. Joint supply response is offered as a conceptual framework to analyze the inevitable externalities attending passage of time. An empirical analysis of pheasant productivity resultant from irrigation development is then presented.

"Resource Stocks and Supply Estimation: An Alternative Approach." Ivar E. Strand and Robert G. Chambers (University of Maryland)
An approach to resource supply estimation is developed which circumvents the need for direct observations in the resource stock. Estimation of supply response in this framework also will permit direct estimation of several important biological parameters from economic data.

Implications of Pesticide and Herbicide Restrictions (Paul H. Gessaman, University of Nebraska, Chairperson)

"Ecology and Economics: Differences in Philosophy." Gary D. Lynne and Roy R. Carriker (University of Florida)
Ecology has been referred to as the "subversive science," as man is argued part of the environment, having only limited control. Economics is based on man as a sociocultural being, as opposed to man the animal. Recognition of differences in philosophy must be explicit before real communication can begin.

"Economic Consequences of Restrictions on Herbicides Currently Used on Indiana Farms." Christopher M. Cashman (Smith-Kline Corporation), Marshall A. Martin, and Bruce A. McCarl (Purdue University)
This study analyzed the farm-level economic consequences of possible bans on herbicides commonly used in corn and soybean production. The empirical results indicate significant short-run yield and income losses, harvest delays, and increased use of labor and machinery from most herbicide bans.

"Multiple Cropping and Pest Control Intensity—Preliminary Economic Results." James E. Epperson and John R. Allison (University of Georgia, Griffin Experiment Station)
The ability to multiple crop in the southern coastal plain of the United States may allow cultural means that favor less intensive pest control. One of three cropping systems under investigation which was selected for economic evaluation showed that within the range of pest control intensities studied, less intensive control resulted in higher net returns.

"Restrictions on Herbicide Use: An Analysis of the Economic Impacts on U.S. Agriculture." Robert O. Burton (West Virginia University) and Marshall A. Martin (Purdue University)
This study analyzed the national and regional economic consequences of restrictions on herbicide use in the United States. The impacts of restrictions on a single corn or soybean herbicide would be small because alternative herbicides would be available. The impacts of restrictions on all herbicides would be much larger.

Quantitative Approaches (W. Arden Colette, University of Florida, Chairperson)

"A Comprehensive Evaluation of Interrelated Pesticide Regulations." Wen-Yuan Huang, Reuben N. Weisz, Gail Willette (NRED ESCS USDA), and Earl O. Heady (Iowa State University)
A hybrid model which links a national econometric model with an interregional programming model is used to evaluate national and regional economic impacts of a DBCP ban on soybeans, a toxaphene ban on cotton, and a simultaneous ban of both pesticides. Preliminary results indicate: the DBCP ban has no production and price changes on soybeans and other major crops. However, the toxaphene ban and the simultaneous ban have a decrease in production and an increase in price of cotton. Some cross-commodity effects are also noticed. The Delta region suffers the greatest net income reduction, followed by the Southeast and Southern Plains, while the Mountain, Appalachian, and Corn Belt regions have substantial increases in net income over time.

"The Grange's Method for Plant Location Studies." Robert L. Beck and J. Don Goodin (University of Kentucky)
The Grange's Method, a subroutine of the Stollsteimer model, was used to identify the optimum number and location of plants needed to process current and future suppliers of manufacturing milk in Kentucky. The use of existing plant sites and capacities adds a dimension of "real world" acceptability to the results.

"Planning and Evaluating Research on Poultry Nutrition: The Role of a Bioeconomic Model." Kurt K. Klein, Greig A. Birchfield, and Raymond E. Salmon (Agriculture Canada)
A linear programming model of turkey production was constructed to help in evaluating research results and planning new projects. It maximizes profits per lot subject to nutrient, ingredient, feed quantity, sex ratio, and production capacity constraints. Applications to date include analyses of feeding trials involving various protein sources and establishing priorities for new research.

"Use of Computer Graphics in the Development and Evaluation of Production Response Surfaces." Richard A. Schoney, Ted F. Bay, and John F. Moncrief (University of Wisconsin)
Various statistical measures and prior knowledge of functional relationships traditionally have been the main guides in developing production response equations. Computer graphics provide a valuable addition to this developmental process. Through graphics, the characteristics of a large volume of data can be analyzed visually. In addition, the physical characteristics of alternative functional forms can more easily be compared to the original data. Computer graphics were used to analyze raw data through surface and contour plots and to compare three alternative functional forms chosen to represent the data. The example cited demonstrated the potential advantage of using computer graphics as a visual research tool in production studies.

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Award-Winning Theses

Callaway, John M., Jr. "The Optimal Use of Surface Water with Return Flows Present: A Theoretical Model for Deriving Alternative Allocation Rules." M.S. thesis, University of Minnesota, 1979.

In many of the river basins in the western United States, downstream appropriators of surface water are heavily dependent upon return flows generated by upstream uses. As a result, transfers of surface water rights between nonadjacent appropriators have the potential to disrupt the configuration of surface flows at both intermediate and downstream locations. While the provisions governing the transfer of water rights in most western states deal with this problem by protecting third parties from potential injury caused by reduced streamflows, the objective of economic efficiency is not well served in the process.

In view of the problem of mutually interfering use associated with return flow externalities, the purpose of this study was to develop alternative rules for allocating surface water that are consistent with the objective of economic efficiency. This was accomplished through the formulation of a static analytical model of a hypothetical river basin, the objective of which was to maximize the sum of producer's willingness to pay for surface water subject to the physical constraints of the water delivery system in the basin which included the availability of return flows. Subsequent analysis of the Kuhn-Tucker conditions for this model yielded optimal pricing rules that were consistent with conventional wisdom regarding depletable externalities. A quadratic programming model was then used to show how these pricing rules could be applied in practice to achieve an optimal allocation of surface water by the alternative means of sole ownership pricing, the creation of return flow markets, and the reassignment of property rights in the event of subsequent transfers. An examination of the institutional problems associated with these methods suggested that economic efficiency could be achieved more easily through decentralized management of return flow markets and reassignment of property rights.

Sanchez, Manuel. "Updating Methods for Adaptive Econometric Models." M.S. thesis, University of Missouri, 1979.

This study examines the problem of updating simultaneous equations models of the agricultural sector. The topic is specialized, as updating is assumed to take place in the structural representation of the system. It is also assumed that the new information is in the form of added sample observations and/or alternative parameter hypotheses. Updating with alternative parameter hypotheses is a method for incorporating the a priori information about how the structural coefficients will evolve over time. The specific components of the study include: (*a*) characterizing the problem of updating with variational parameter hypotheses and additional sample observation, (*b*) developing efficient estimation methods for updating when the two sources of information are used separately or merged, (*c*) illustrating the process of updating in an applied context, (*d*) evaluating the results of the applied updating exercise, and (*e*) assessing the implications of the incorporated additional information and developing guidelines for use of updating in large-scale modeling for the agricultural sector.

Major conclusions of the study relate to updating methods and the applied modeling exercise. For the former, various optimal design concepts were integrated with mixed estimation, forecasting, and simultaneous equations methods to develop an approach for updating in situations with passively generated sample data. These results provide an operational basis for updating large-scale models and for evaluating updated structures. In the application, the results showed that the introduction of variational parameter structures should be justified on a priori grounds if updating is to result in improved model representations. These results are somewhat at variance with those which have been derived for updating reduced form representations.

Stavins, Robert N. "Forecasting the Size Distribution of Farms: A Methodological Analysis of the Dairy Industry in New York State." M.S. thesis, Cornell University, 1979.

This study has five main objectives: (*a*) to describe and analyze patterns of structural change in the New York State dairy industry in terms of the number and size of producers, (*b*) to compare alternative methods of forecasting the future size distribution of producers, (*c*) to select and apply the most appropriate forecasting method to an actual prediction of the future size-structure of dairy farming in the state, (*d*) to analyze the implications of the forecast in terms of the future supply of milk, and (*e*) to demonstrate a technique which may have a wide range of uses in market structure analysis and also may facilitate reasonable supply predictions.

As a means to identify an appropriate method for predicting the 1985 size distribution of New York dairy farms, sixteen approaches are considered. Nine of these are judged to be potentially credible methods and so are examined in greater detail, each being evaluated in terms of theoretical soundness,

data requirements, computational costs, and predictive accuracy.

A variable Markov multinomial logit model is identified as being the most appropriate predictive method and is utilized in making conditional forecasts of the 1985 farm size distribution.

Results of the study indicate that although future change in the size-structure of New York State dairy farming will continue to be mainly in the form of increased mean size of farm; it is also likely that the shape of the size distribution will change significantly more than it has in the recent past, its skewness becoming more pronounced.

Capps, Oral, Jr. "The Impacts of Selected Nonfoods, Foods, Socioeconomic, and Demographic Characteristics on the Decision to Purchase Various Meats and Seafoods for Home Consumption." Ph.D. thesis, Virginia Polytechnic Institute and State University, 1979.

A static complete systems framework was employed to identify and assess factors that affect choices among various meats and seafood for home consumption. The traditional econometric model of food demand was extended to provide a more comprehensive analysis of food consumption and information for decision making and policy formulation for the meat and seafood industry. Additionally, a comparison of alternative statistical models in terms of both their theoretical properties and empirical usefulness was provided and some general principles for workable criteria of model specification for demand systems were developed.

Two issues in empirical demand analysis were explored: (*a*) estimation of complete systems of demand equations using household budget data, and (*b*) incorporation of household characteristics into such systems. The 1972–73 BLS Consumer Expenditure Diary Survey was the data source. Demand systems under consideration were the S_1-branch system and constant elasticity of demand. For each, both with and without household characteristics, estimates were obtained of own-price, cross-price, and income elasticities, marginal budget shares, and system parameters for four regions and the United States as a whole.

The S_1-branch system, and to a lesser degree the CEDS, presented reasonably realistic pictures of national and regional household demand patterns. Although the former system generated more reliable structural estimates, the latter was useful in forecasting quantities purchased. Demands for meat and seafood commodities were extremely sensitive to own prices and income changes. Substitute and complementary goods prices and household characteristics, although important in terms of magnitude of impacts, were of less consequence. Under the assumption that future changes in prices, income, and household characteristics would resemble those occurring 1977–79, quantity demanded and total revenue of pork and poultry products at the retail level increased substantially, while quantity demanded and total revenue of beef products decreased dramatically.

Johnson, Donald Allan. "Investment, Production, and Marketing Strategies for an Iowa Farmer-Cattle Feeder in a Risky Environment." Ph.D. thesis, Iowa State University, 1979.

The purpose of this study was to analyze how a farmer-cattle feeder could manage risk arising from fluctuations in prices as well as crop yields. A model was developed which allowed a farmer to react to risk through choice of investment, production, and marketing strategies.

Maximization of expected utility was assumed to be the farmer's goal. To justify using quadratic programming, a set of sufficient conditions for transforming expected utility problems into mean-variance analyses was developed. These conditions, plus others already developed, were considered appropriate to risk problems typically analyzed.

The actual model was structured as a multiperiod quadratic program using maximization of expected utility of net worth as an objective. Initially, capital gains on assets were included in the net worth; later, for comparison purposes, capital gains were excluded. Options that a farmer could choose among included (*a*) investments in land, machinery, and feedlots; (*b*) production of corn, soybeans, and slaughter cattle; and (*c*) a number of cash and futures marketing activities for produced commodities.

Three different parametric quadratic programming models were solved and a number of empirical results of interest to farmers were obtained. One of the key findings was that a farmer must reduce the scale of his farming operation to reduce risk. Another important result was that using additional marketing strategies would allow a farmer to assume more risk in production and investment. Finally, cattle feeding was found to be a feasible addition to cash grain farms even when risk is considered.

Nygaard, David F. "Risk and Allocative Errors Due to Imperfect Information: The Impact on Wheat Technology in Tunisia." Ph.D. thesis, University of Minnesota, 1979.

This thesis estimates the importance and effect of producer uncertainty, risk preferences, and imperfect information on wheat production in Tunisia, particularly with respect to the use of modern inputs and the adoption of new varieties. First, a model is presented which permits the estimation of the risk preferences of agricultural producers.

Based on producer's perceptions of the production process and response to these perceptions, a risk parameter is estimated.

Second, producer perceptions of the production process at the time of seed bed preparation are compared with the production process realized at harvest. Mistaken perceptions of input-output relationships cause allocative errors which result in lower economic returns to wheat production. It is hypothesized that the errors are larger for the production of newer unknown varieties than for the ordinary varieties and that the allocative error decreases as a producer gains experience growing a particular variety.

The model is empirically tested on durum wheat producers in Tunisia. One hundred and twenty-five farmers in northern Tunisia were visited twice during the 1976/77 season. The first visit occurred shortly after the wheat was planted and most input decisions had been made. A second visit took place after the grain was harvested.

Results indicate that 73% of the farmers in the sample are risk-averse. Farmers with poorer soil and/or smaller holdings tend to be more risk-averse than younger ones. This risk aversion discourages farmers from using economically optimum levels of modern inputs, resulting in a significant cost to Tunisia in foregone wheat production. Risk aversion also inhibits the adoption of high-yielding varieties of durum wheat which are perceived to have more variable economic returns than ordinary varieties.

Comparisons of perceived and true costs indicate that substantial allocative errors are made, caused by misperceptions of the production parameters. Errors are significantly higher for high-yielding varieties and decrease as farmers gain experience.

The impact of income variability and risk aversion on wheat productivity encourages efforts aimed at stabilizing incomes. Perceptions of production processes are subjective and uncertain. Efforts to influence these perceptions can increase the rate of adoption of a new technology and economic returns to that activity.

Table 4. U.S. Department of Labor Grant Operating Statement, 31 December 1979, with Comparisons

Item	1973	1974	1975	1976	1977	1978	1979
				($)			
Begin balance	0	25,100.34	7,434.10	8,844.22	−753.05	−15,002.57	−19,741.80
Amount received	37,500.00	32,000.00	49,500.00	22,000.00	15,000.00	0	23,535.00
Expenses	12,399.66	49,666.24	48,089.88	31,597.27	29,249.52	4,739.23	2,555.02
Ending balance	25,100.34	7,434.10	8,844.22	−753.05	−15,002.57	−19,741.80	1,238.18

Table 5. Income-Expense Statement of Editor's Office, 1979

Item	1977	1978	1979
Income:		($)	
AAEA Appropriation:			
Journal	20,000,00	22,500.00	24,500.00
Newsletter	0	0	1,000.00
Total income	20,000.00	22,500.00	25,500.00
Expenses:			
Salaries and fringes of Assistant Editor and Secretary	19,133.00	21,398.75	23,518.20
Postage and telephone	1,607.00	1,961.52	3,068.48
Supplies	945.00	380.72	413.43
Total expenses	21,685.00	23,740.99	27,000.11
Balance	−1,685.00	−1,240.99	−1,500.11

Table 6. Combined Balance Sheet, 31 December 1979, with Comparisons

Item	1975	1976	1977	1978	1979
Assets			($)		
Cash-bank	54,940.54	12,321.25	47,361.82	12,968.72	619.19
Cash-bank (USDL)	8,844.22	0	0	0	1,238.18
Cash-UK	1,714.21	3,510.28	4,982.99	6,740.76	1,358.77
Cash-broker	10,937.23	1,546.92	4,205.57	4,651.28	1,076.00
Accounts receivable	0	0	0	0	35,555.95
Investments					
Certificate of deposit	0	40,000.00	40,000.00	85,046.17	1,091.52
Ready asset	0	7,546.43	15,568.23	26,167.55	166,333.54
Stocks (at cost)	102,551.99	102,551.99	102,551.99	129,366.50	164,985.54
Bonds (at cost)	0	0	0	49,631.76	89,633.76
App. market value (stocks)	159,310.125	202,490.50	175,042.125	178,233.375	212,667.00
App. market value (bonds)	0	0	0	46,092.40	84,918.80
Total assets (at market value)	235,746.325	267,415.38	288,160.735	359,900.255	504,858.95
Total assets (at cost)	178,988.19	167,476.87	214,670.60	314,572.74	461,892.45
Liabilities					
USDL unspent funds	8,844.22	(753.05)	(15,002.57)	(19,741.80)	1,238.18
Prepaid dues	49,868.50	30,604.50	50,430.75	66,177.50	78,032.62
Accounts payable	30,116.10	30,116.10	23,116.10	23,116.10	23,000.00
Net worth (at cost)	90,159.37	107,509.32	156,126.32	245,020.94	359,621.65
Net worth (at market value)	146,917.505	207,447.83	229,616.455	290,348.455	402,588.15
Total liabilities (at market value)	235,746.325	267,415.38	288,160.735	359,900.25	504,858.95
Total liabilities (at cost)	178,988.19	167,476.87	214,670.60	314,572.74	461,892.45

came at the expense of *Journal* advertising income. The miscellaneous expenses include $498.70 for refunds already recorded as income, $148.44 loss on a bond purchased, $54.00 for copyright fees, $1.00 registration fee, $250.00 dues for statistics, $58.00 for workmen's compensation, $5,000 in grants, $692.12 for exchange charges, bad checks, etc.

The National Registry project started 1979 with a negative $19,741.80, but we received $23,535 toward the USDL grant and spent $2,555.02, leaving a balance of $1,238.18 (table 4). The project was modified in June 1980 for the thirteenth time and was extended to 30 June 1981, at which time the balance of the grant, $10,404, will be forthcoming upon completion of the final report.

In accordance with the policy established in 1973, the Editor provided the income-expense statement for editorial support for 1979 and it is incorporated as a part of this report (table 5). It showed a deficit of $1,500.11.

The Balance Sheet for AAEA showed again considerable improvement, with $114,600.71 added to our net worth as compared to $88,894.62 in 1978 and $48,617.00 (table 6). Officially, the assets are carried on the books at cost. However, market values are shown for your information. Based on cost, the net worth of AAEA has quadrupled during the past four years. A serious problem has suddenly emerged, and that is the accounts receivable. We are increasingly having trouble collecting our bills on time. One additional comment is that over $500,000 went through the bank from about 14,000 checks and something more than that amount went through our stockbroker at my direction. The point is that this represents many thousands of transactions and record keeping, and it is getting larger.

This report covers my tenth year. The Association is currently healthy, viable, and active. With inflation and pressures for increased support for more and more activities, the question soon to be faced is, what services do you want from the AAEA and are you willing to pay for them? I sincerely enjoyed serving as your Secretary-Treasurer for the past decade.

John C. Redman, secretary-treasurer

Report of the Investment Committee

The portfolio subcommittee of the Finance Committee was active during 1979. The portfolio, which went through many changes, produced an income of $28,788.95, or a 72% increase over 1978. All assets carried on the books at cost of $422,044.36 had a market value of $465,010.86 at the end of the year (table 1). However, a large part consisted of near cash. The detail on our stocks—the issue, amount, cost, dividends, market value, including sales and purchases—is shown in table 2, and the detail on our bonds is shown in table 3. Because of the high interest rates, we chose to let debt issues constitute a large portion of our portfolio. I use our Money Mart Asset account heavily to earn a high rate of return on funds not invested or not needed for immediate payment of bills.

The portfolio subcommittee, consisting of chairman John Brake, Richard Feltner, and me, has been active in trying to manage the portfolio well.

John C. Redman

Table 1. AAEA Summary of Investments, Year Ending 31 December 1979

	Income	Value	
	1 Jan.–31 Dec. 1979	Cost	Market
	($)		
Stocks:			
On hand, 1 Jan. 1979		129,366.50	178,233.375
On hand, 31 Dec. 1979		164,984.54	212,667.00
Dividends	12,995.24		
Bonds:			
On hand, 1 Jan. 1979		49,631.76	46,092.40
On hand, 31 Dec. 1979		89,633.76	84,918.80
Interest	5,612.50		
Miscellaneous[a]			
Money Mart Asset trust, 31 Dec. 1979	9,635.86	166,333.54	166,333.54
Savings account, 31 Dec. 1979	545.35	1,091.52	1,091.52
Total (31 Dec.)	28,788.95	422,044.36	465,010.86

[a] Amount fluctuates.

Table 2. AAEA Stocks, 31 December 1979

Company	No. of Shares	Original Cost	Dividends 1979	Market Value 31 Dec. 1978	Market Value 31 Dec. 1979
		($)			
Am. Cyanamid	500	15,073.43	800.00	12,687.50	17,000.00
Am. Home Prod.	200[a]	5,636.05	300.00	0	5,450.00
Am. Tel. & Tel.	603[b]	28,355.11	2,592.45	17,424.00	31,431.375
Am. T&T $4CV	0[b]	0	300.00	19,050.00	0
Borden	300[b]	4,309.09	538.50	7,650.00	7,162.50
CIT Financial	0[c]	0	750.00	9,412.50	0
Chase Manhattan	93	1,115.09	223.20	2,731.875	3,592.125
Com. Edison	232	7,467.14	603.20	5,974.00	4,640.00
Cont. Corp.	400[d]	10,161.33	200.00	0	10,650.00
Cont. Group	225	4,315.38	506.25	6,075.00	6,496.875
Exxon	306	10,325.36	1,193.40	15,032.25	16,868.25
Foremost-McKess	400[e]	10,161.33	0	0	10,300.00
Girard	400[f]	10,767.96	0	0	10,200.00
Goodyear	500	16,692.50	650.00	8,062.50	6,437.50
Jewell	150	3,875.94	243.00	3,018.75	3,937.50
MMM	200[g]	10,626.79	120.00	0	10,050.00
NICOR $1.90CV	7	0	13.32	182.00	231.875
Santa Fe Ind.	300	10,299.00	705.00	8,850.00	15,600.00
Sears Roebuck	608	1,845.38	753.92	12,008.00	10,944.00
Southern Pac.	300[h]	10,280.32	195.00	0	10,125.00
Std. Oil Ind.	400[i]	3,678.34	2,100.00	45,300.00	31,550.00
Texaco	0[j]	0	208.00	4,775.00	0
Total		164,985.54	12,995.24	178,233.375	212,667.00

[a] Bought 200 shares @27-5/8 = $5,636.05 on 2 Feb. 1979.
[b] Exchange 300 shares of AT&T$4CV for 315 shares of AT&T + $48.36 on 2 Feb. 1979.
[c] Sold 300 shares @60 = $17,759.40 (net) on 5 Oct. 1979. Cost 34-7/8 or $10,639.50 on 22 May 1978 for a gain of $7,119.90.
[d] Bought 400 shares @25 = $10,161.38 on 9 Oct. 1979.
[e] Bought 400 shares @25 = $10,161.38 on 9 Oct. 1979.
[f] Bought 400 shares @26-1/2 = $10,767.96 on 10 Oct. 1979.
[g] Bought 200 shares @52-3/8 = $10,626.79 on 28 Sep. 1979.
[h] Bought 300 shares @33-3/4 = $10,280.32 on 10 Oct. 1979.
[i] Sold 400 shares @71-1/4 = $28,179.05 (net) on 11 Oct. 1979. Cost $3,678.34 for a gain of $24,500.71.
[j] Sold 200 shares @26 = $5,078.66 (net) on 5 June 1979. Cost $7,696.90 for a loss of $2,618.24.

Table 3. AAEA Bonds, 31 December 1979

	Cost	Int. 1979	Market Value 31 December 1979
	($)		
CIT Fin., 7-5/8 81 RG[a]	19,628.61	1,525.00	18,400.00
Comm. Cr. Corp., 8-78 86 RG[b]	10,164.79	887.50	8,700.00
Fed. L. Bank, 7.3 82[c]	19,838.36	1,460.00	18,187.60
Fed. Farm Cr. Bk., 14.35 80[d]	40,002.00	0	39,631.20
Fed. Farm Cr. Bk., 10.8 79[e]	0	1,740.00	
Total	89,633.76	5,612.50	84,918.80

[a] Purchased $20,000 @96 + 428.61 = $19,628.61 on 23 Aug. 1978.
[b] Purchased $10,000 @101.5 + 14.79 = $10,164.79 on 7 Mar. 1978.
[c] Purchased $10,000 @96.875 + 249.42 = $9,936.92 on 23 Aug. 1978. $10,000 @96.5 + 251.44 = $9,901.44 on 24 Aug. 1978.
[d] Purchased $40,000 @100 + 2.00 = $40,002.00 on 25 Oct. 1979.
[e] Purchased $25,000 @100-19/32 + 277.50 (int.) = $25,425.94 on 2 Feb. 1979. Matured 1 Oct. 1979, giving 148.44 loss and $277.50 recovery of interest.

Report of the Finance Committee

This annual report covers the activities of the Finance Committee for the period August 1979 to July 1980. The primary activities of the Finance Committee during this period have been to monitor AAEA income and expenses, prepare the 1981 budget, recommend changes in the investment portfolio, and evaluate budget implications of transferring the secretary-treasurer's office. Members of the committee are Joe Coffey, chairman (Virginia Tech); John Brake (Michigan State); John Hopkin

(Texas A&M); Dick Feltner (Louisville (FIBC); and John Redman (Kentucky).

AAEA Financial Condition

The Finance Committee submitted to the December 1979 Atlanta Board meeting a report on the income and expenses of the Association. This report has been updated and is included herein as tables 1 and 2. These tables indicate that the AAEA is in a healthy financial condition. Income exceeded expenses during the calendar year 1978 by $88,894 and in 1979 by $114,601. Currently, it is projected that 1980 income will exceed expenditures by $9,350. Because AAEA operates on a cash rather than an accrual accounting basis, the income and expense balances must be interpreted with care because in some years, the expenses may reflect payments for four issues of the *Journal*, while in other years, it may reflect payments for seven issues. Furthermore, sales of stocks show up as income. Despite these distortions inherent in a cash accounting system, AAEA has strengthened its financial position during the past three years without a membership dues increase.

Portfolio Changes

The investment portfolio committee of the Finance Committee, under the chairmanship of John Brake, with Richard Feltner and John Redman as members, has closely monitored AAEA's investment portfolio and recommended changes in the portfolio which have been approved by the Finance Commit-

Table 1. AAEA Actual Expenses and Budgets, July 1980

	Actual Expenses		Approved Budgets		
Description	1978	1979	1979	1980	1981
	($)				
Journal:					
Printing	71,543[a]	113,359[b]	85,000	90,100	86,900
Postage and storage	0	0	14,250	15,000	16,000
Editorial support	22,500	24,500	24,500	28,000	40,500
Printing reprints	5,916	7,728	7,300	7,000	8,000
Editor transfer	0	0	0	12,000	0
Subtotal	99,959	145,587	131,050	152,100	151,400
Newsletter:					
Printing	670	n/a	6,500	6,000	6,700
Postage		n/a	3,300	3,300	3,500
Editorial		n/a	1,200	1,100	1,600
Subtotal	670	9,455	11,000	10,400	11,800
Literature Retrieval Document. Ctr.	15,000	15,000	15,000	17,000	19,000
Survey Agr. Econ. Lit. Guarantee	14,755	3,598	7,500	8,000	10,000
Intl. Conf. Travel Grant	0	0	2,500	0	0
Awards	1,109	1,767	1,500	1,500	1,500
Annual meeting	5,251	1,982	3,000	3,000	3,000
Registry	n/a	n/a	500	500	500
COPAFS and FSAS[c]	0	0	0	2,000	2,400
Subtotal	36,115	22,347	30,000	32,000	32,400
General operations:					
Postage and phone	4,141	4,360	7,500	9,000	11,000
Office supplies and printing	8,586	6,039	6,000	6,000	6,000
Committees	488	61	1,500	1,500	1,500
Bonds and audit	615	615	750	750	1,000
Equipment Purchase and Service	11,500	0	2,900	0	0
Sec.-Treas. clerical assistant	17,338	17,369	19,000	20,000	23,000
Sec.-Treas. honorarium	5,000	5,000	5,000	5,000	20,000
Miscellaneous	1,884	6,702	0	3,800	5,000
Sec.-Treas. transfer	0	0	0	15,000	0
Subtotal	49,552	40,146	42,650	61,050	67,600
Total expenses	186,296	217,535	214,700	225,550	267,200

[a] For four (4) issues.
[b] For seven (7) issues.
[c] Committee of Professional Associations on Federal Statistics and Federation of Scientific Agricultural Societies.

Table 2. AAEA Actual Income and Budgets, July 1980

	Actual Income		Approved Budgets		
Description	1978	1979	1979	1980	1981
	($)				
Dues and subscriptions					
Regular members	100,103	90,203	92,500	92,500	91,950
Senior members	825	687	1,250	1,250	1,325
Junior members	8,116	9,959	6,250	6,250	6,612
Libraries	56,241	74,516	63,087	61,000	67,585
Institutional	3,200	3,400	3,500	3,500	3,200
Subtotal	168,485	178,765	166,587	164,500	170,672
Journal publications					
Journal sales	7,816	16,834	8,500	8,500	8,500
Page charges and reprints	36,023	52,241	30,000	36,000	36,000
Advertisements	1,196	1,035	1,000	1,000	800
Royalties	4,260	337	1,000	1,000	1,000
Newsletter ads	0	2,570	1,000	4,200	3,000
Subtotal	49,295	73,017	41,500	50,700	49,300
Survey Agr. Econ. Literature	13,738	6,154	10,000	0	0
Investments	16,778	28,789	17,500	23,000	25,000
Annual meeting	2,000	8,647	3,000	3,000	3,000
Address labels	1,141	1,891	1,500	1,500	1,500
Miscellaneous	2,643	5,822	300	300	5,000
Gain (loss) stock sales	21,120	29,051	0	0	0
Subtotal	57,410	80,354	32,300	27,800	34,500
Total income	275,190	332,136	240,387	243,000	254,472
Balance (income minus expenses)	88,894	114,601	25,687	−12,500	−12,728

tee. In October, the Finance Committee received Board approval for the sale of $28,500 of common stock, the purchase of $50,000 of common stock, and the purchase of a $40,000 eight-month bond at 14.35% interest.

The Finance Committee exercised its authority twice to buy or sell common stocks equal in value up to 15% of the portfolio between Board meetings. Three hundred shares of CIT were sold at $60 on 5 October and 400 shares of Diamond Shamrock at $29-7/8 per share and 600 shares of Browning-Ferris at $17-1/8 per share were purchased on 10 June 1980.

Portfolio Earnings and Market Value

The market value of assets in the AAEA portfolio increased from approximately $360,000 on 31 December 1978, to $505,000 on 31 December 1979. The major source of this difference is an increase in accounts receivable of $35,000 and an increase in Ready Asset account of $140,000. During the 1979 calendar year, the Association had a return including appreciation in the market value of stocks and dividends of $40,810, resulting in a combined yield on stocks of 17.3%. This compares with a 17.1% return based on the Standard-Poor Composite. As of 31 December 1979, the investment portfolio consisted of $161,334 of money market assets, $84,919 of bonds, and $212,667 of stocks.

Changes in the 1980 Budget

On the income side, the budget changes are (*a*) an increase from $36,000 to $47,000 in page charges due to the expected reimbursement from ESCS for the November 1979 special *Journal* issue on regulation; (*b*) a decrease in Newsletter ad revenue from $4,200 to $3,000; (*c*) an increase in investment portfolio revenues from $23,000 to $30,000; and (*d*) an increase in annual meeting revenues from $3,000 to $5,100.

The combined effect of these changes is to change the 1980 budget from a project deficit of $12,500 to a surplus of $9,350.

1981 Approved Budget

The 1981 approved budget follows closely the budgets for 1979 and 1980. The key items are as follows:

(*a*) A $3,200 reduction in *Journal* printing costs based on an assumed 1,100 pages at $79 per page and an increase in editorial support.

(*b*) The AAEA has an agreement with the University of Minnesota Press to guarantee $10,000 for the printing of each volume of the *Survey of Agricultural Economics Literature*. In return, the AAEA receives a 22.5% royalty. In 1981, it is expected that the fourth volume will be printed requir-

ing a guarantee of $10,000, but royalty income is not expected until 1982.

(*c*) A new item in the 1981 budget is a $400 fee to be paid to the Federation of Scientific Agricultural Societies (FSAS). The purpose of FSAS is to provide a forum for interdisciplinary communication and to enhance the capability of the scientific agricultural societies to speak with a unified voice.

(*d*) The Board voted at the 1979 Pullman meeting to join the Committee of Professional Associations on Federal Statistics for three years at $2,000 per year.

(*e*) The proposed budget for the new Secretary-Treasurer's office at Iowa State includes $43,100 for personnel and $19,500 for postage, phone, supplies, printing, etc.

(*f*) The Association jointly sponsors a Literature Retrieval Documentation Center with ESCS and the $19,000 is the Association's anticipated expenses.

Overall, the 1981 proposed budget has a total expenditure of $267,200, an increase of $11,500 over the 1980 approved budget.

Income from dues and subscriptions are the major revenues for the Association. The 1981 proposed budget revenues are based upon the 1976–79 average number of subscriptions in each of the classes of membership multiplied by the subscription rate resulting in a projected revenue of $170,672. The other revenue estimates are similar to those for previous years. The total projected income of $254,472 is lower than expenses resulting in a $12,728 deficit.

Due to the uncertainties of the Secretary-Treasurer's expenses, the inclusion of a $5,000 miscellaneous expenses, and a sizeable investment portfolio, a dues increase does not appear needed at the present. However, the projected deficit does indicate that a dues increase may be needed in 1982.

Joseph D. Coffey, chairman

Report of Tellers Committee

Ballots received from the secretary-treasurer of the American Agricultural Economics Association were counted in accordance with the bylaws of the Association to preserve the secrecy of the ballots. Candidates receiving the largest number of votes were: G. Edward Schuh for president-elect and William E. Martin and Richard G. Heifner for directors.

Joe T. Davis
Angelos Pagoulatos

Report of the Editor

A total of 276 new manuscripts were submitted in 1979–80, compared to 307 last year and 269 in the first year of our editorship. We accepted 111 manuscripts for an acceptance rate of 40.2%. We expect to publish 67 Proceedings papers. Herb Stoevener reports that during the past three years, he processed 357 volumes for the Books Received list, of which 78 books were reviewed in the *Journal*.

Because of my position as editor, I participated in the editing of the Proceedings of a research priorities conference of the animal sciences. To be published this fall, the Proceedings will be entitled *Animal Agriculture: Research to Meet Human Needs in the 21st Century*.

Manuscripts are submitted much more frequently from some institutions than from others. During 1978–80, the top five universities in submissions were: Purdue (44 manuscripts with one or more authors at Purdue), Texas A&M (39), Illinois (31), Georgia (31), and California/Berkeley (29). USDA/Washington led the employer list with 54 submissions.

Multiple authors are fairly common. The 852 manuscripts had a total of 1,450 authors—an average of 1.7 per manuscript.

The *Newsletter* seems to be going well. However, its tardy delivery overseas has been an aggravation that cannot be solved short of extraordinary costs.

Considerable difficulties have been encountered this year with Heffernan Press in both their tardiness in meeting publication deadlines and in billing incorrectly. We hope that both problems have been solved as we pass the editorial task to the new editors.

As outgoing editor, it seems appropriate to reflect a bit on the *Journal*. I am quite aware that it does not contain the variety of lively, broad, policy-oriented papers that a great many of our members say they want to read. Few such papers arrive at an editor's desk. An editor faces an impossible task of bridging the gap between what authors—and most reviewers—want published and what many members say that they want to read. Certainly it is within the prerogative of various segments of the membership to press their desires upon its leadership. My modest point is in tune with the political and economic times: as readers, please moderate your expectations.

The sorting process is difficult. Manuscript quality appears to be distributed much like a normal curve. There are some obvious acceptances and more obvious rejections, but a majority of manuscripts are in that middle arena. I appreciate the self-restraint with which authors have received their rejection letters. I believe that most good manuscripts will be published somewhere if the author is persistent. Nevertheless, I know the sting of the rejection slip; sending so many is one of the more onerous parts of this job.

The editorship has its rewards. One of the greatest is the continual contact with the many active minds of authors and reviewers. The profession is indebted to their contributions. Another reward

Committee Reports

Report of the President

This has been a busy year for the officers of your Association. The format and content of this meeting was designed by the Executive Board sitting as a program committee last November here in Urbana. The mid-year Board business meeting was held in conjunction with the ASSA assembly in Atlanta between Christmas and New Year's Day. A special Board meeting was held in Atlanta in April to consider arrangements for the Secretary Treasurer's office. And, as is the usual practice, a two-day meeting of the Board was held here last Saturday and Sunday to receive committee reports, prepare budgets and to conduct the regular business activities of AAEA.

This three-day meeting is an example of the wide participation in the affairs of the Association. As President, I had the responsibility for inviting speakers in our general sessions. The President-Elect took responsibility for putting together the nine invited paper sessions with the assistance of board members. The selected papers committee chaired by Don Mitchell and Dave Watt and their 16 committee people chose the 132 papers that are being read here. Bud Stanton, Luther Tweeten, and I studied 44 organized symposium proposals that were received from members before choosing 16 for the program.

Progress during the past year can be attributed largely to the work of the many committees of the Association. In the next few minutes I would like to touch on some of the highlights of their activities. These may be grouped in three categories: (*a*) membership services, (*b*) outreach and liaison efforts, and (*c*) management of association affairs.

Membership Services

The work of the several awards committees and the chairmanship of Dan Padberg will be completed this evening in the recognition of outstanding achievement in eight different areas of activity of the profession at the annual awards banquet. Many hours by more than eighty members of the Association go into the successful completion of this selection process. An updated version of these awards conditions will be prepared and distributed this fall to make sure they are readily accessible to all members of the Association.

The Postwar Literature Review is nearing completion. Volume 3 will be going to press this fall, and the final volume dealing with economic development will follow early next year. Distribution of this series is in the hands of the University of Minnesota Press with a 30% discount to be extended to AAEA members who purchase volume 3 when it is released.

The Resident Instruction Committee is to be congratulated for its outstanding teaching workshop held last week in Carbondale. The theme was "Are You Communicating?" Bill Herr and his associates are already thinking about the sponsorship of such workshops on a regular basis. Financial assistance for travel grants was provided by the Farm Foundation and registration grants by AAEA. Some seventy-five persons participated, representing thirty different institutions. Abstracts will be printed in *AJAE,* December issue.

The Student Section of AAEA adopted a new constitution yesterday and the Executive Board amended the Bylaws of AAEA to provide for a more effective relationship between undergraduate student chapters and the Association. The change provides for three faculty advisors on the Student Section Executive Committee, more independent operation of financial affairs by SS-AAEA, and better coordination between SS and AAEA committees and Executive Board. You will note the wide range of student activities at this meeting.

The Industry Commitee has been active this year under Dick Crowder's able leadership. An invited paper session was organized, a highly successful banquet arranged for last evening, and lots of activity on new ideas for expanding membership and services to this important segment of our membership.

Extension folk have been most helpful in proposing organized symposia, submitting papers, and participation in Executive Board work. John Ikerd's committee met yesterday to discuss plans for an Extension workshop at the time of the Clemson meeting next summer. We will hear more about that later.

The International Committee, too, had a highly successful banquet last evening. The AAEA-AID Cooperative Agreement for an International Training Study was successfully completed with a wide variety of papers and publications coming out of this effort, much due to the months of effort devoted to this by Hal Riley and Darrell Fienup but with many other associates. The list of conferences, symposia, seminars, and discussion groups will not fit on two single-spaced typed pages! Congratulations on a fine piece of work.

Now for two areas of membership services where we have some problems. Our Professional Registries work under a Department of Labor contract has been beset with problems of computer changeover, but placements have been going well. The Employment Registries form has been revised and approved with final programming to be completed this fall. Greater use of this service is urged.

A blue-ribbon Literature Retrieval Committee has been at work this year to evaluate this service. I hope you have visited Cynthia Kenyon's stand outside this hall. Some of you may not know that she runs this service year-round at 500 12th Street. Dan Badger's group is working on the problem of visibility for this potentially valuable service, financed in part by your membership dues. Use it!

Outreach and Liaison

Ten travel grants were awarded for AAEA members to attend the 17th International Conference of Agricultural Economists at Banff last September. It was a fine conference in a glorious setting. Talk to Allen Paul or Jim Hildreth to get details on Conference Eighteen, to be held in Jakarta in August 1982.

SEA has expanded contacts with professional agricultural societies in the matter of setting priorities for research, extension, and instruction. The Board is seeking more effective mechanisms to participate in this work. You may wish to drop in on the organized symposium tomorrow morning to add your ideas. The Executive Board has approved participation in a proposed Federation of Scientific Agricultural Societies to assure full consideration of economic dimensions in priority identification and funding.

Although AAEA is not a member association of CAST, many members have made important contributions to the work of CAST task forces, including a number of task force chairpersons. I am sure that Luther Tweeten will continue to receive requests to recommend names of persons with skills particularly suited to new CAST task forces this year.

AAEA will cosponsor a national soil and water research priorities workshop next year. Emery Castle has been asked to serve on the conference planning committee and nominations for committee assignments have been invited. If you have an interest in this area, please mention this to Tweeten or me.

A number of agricultural societies are at work to encourage preparation of a thesaurus of agriculture. We think AAEA participation may be important to see that economic concepts are fully and appropriately represented if such an effort does receive funding.

AAEA will cosponsor two other activities this year. One is an energy symposium with the American Society of Agricultural Engineers, to be held in Kansas City, Missouri in late September. The other deals with the value of weather information, cosponsored with the American Meteorological Society in Boston next January.

Bruce Gardner and his Economic Statistics Committee have provided important inputs into data resources planning, including the Committee of Professional Associations on Federal Statistics (COPAFS) for a trial three-year period and continued representation on the Federal Statistics Users' Conference (FSUC). Gardner also is our representative on the Census Advisory Committee on Agricultural Statistics. Ed Schuh is the AAEA Director for the National Bureau of Economic Research.

AAEA Management

Editorial direction for the period 1981–83 will be provided by the new editor of *AJAE*, James Houck and his associate directors Frank Smith and Ben Sexauer. Ron Schrimper will be the book review editor for volumes 63–65 of our *Journal*. Our sincere appreciation is extended to Jim Rhodes, *AJAE* editor for volumes 60–62, his associate editor Stan Johnson, and their editorial council members for their fine work.

Membership recruitment has been organized by Gene Mathia through regional and local representatives. Suggestions for improving the data base for management of Association affairs have been provided by a committee chaired by Ken Farrell. These efforts should be most helpful in coming years.

During the past year, a great deal of study has gone into planning future arrangements for the office of secretary-treasurer of the Association. You have been kept up to date through the *Newsletter* of the work of John Stovall's committee charged with the responsibility of considering alternative arrangements for the office of secretary-treasurer and a business office, as proposed in the Sundquist committee report that has been discussed in earlier meetings of the Association. Modification of the present structure was called for when the University of Kentucky, having provided generous support for this office for more than ten years, asked that the present arrangement be terminated at the close of the current fiscal year.

Specific actions of the Executive Board are reported in the minutes that are printed with this report. To summarize briefly, the Board reviewed four proposals and by secret ballot unanimously agreed that the Iowa State proposal should be accepted, to take effect not later than 1 January 1981. Dr. Sydney James was appointed Secretary-Treasurer for a term of one year, as provided by Article VI, Section 2 of the Constitution, and the the Board confirmed a commitment of three years, as provided by Article VI, Section 4 of the Bylaws, subject to a performance evaluation each year preceding reappointment.

Dr. James was authorized to create a business office for the Association at Iowa State University and to retain the services of individuals to implement the establishment of this office. Iowa State proposed that Sydney James be named director of the office and Wesley Ebert be named associate director. The Secretary-Treasurer would receive no pay for services in that role but would be paid on a part-time basis as Director of the Business Office. A three-man committee consisting of John Hopkin,

chairman, Tom Brown, and Earl Swanson has been named to formulate and implement plans for transferring the office from the University of Kentucky to Iowa State University.

A resolution of appreciation and special commendation to John Redman for meritorious service as Secretary-Treasurer of the Association since January 1970 was drafted for presentation at this meeting.

In closing, let me express my thanks for your warm support of our efforts during the past year. It has been great. We hope to see you all next year at Clemson.

Richard A. King, president

Report of the Secretary-Treasurer

The AAEA membership for 1979 reached an all time high (table 1). Each year, about 500–600 new members join and about 500–600 drop out, leaving a small gain or loss, depending on response to our efforts. The big turnover occurs in our junior membership and with our A.I.D. memberships. Unless they become rather involved professionally, they join until they graduate or for three years and then drop out. The practice of charging a differential registration fee and of inviting only members to participate in the AAEA activities has been good for the Association. To get the last 1,000 members and last 200–300 libraries to pay requires considerable perseverance.

The number of members who paid their dues on or before 1 April and therefore received a ballot to vote increased by 248, but only 67 more were returned (table 2). This was aided by the fact that if dues were not paid on or before 15 January, the member did not receive the February issue of the *Journal*.

The operating statement for the AAEA business during 1979 showed a record net gain of $114,600.71, as compared to $88,894.62 in 1978 and $48,617.00 in 1977 (table 3). Caution should be noted because in analyzing operating statements, the extraordinary items often convey normal activity. Included in the $114,600.71 gain is a capital gain of $29,050.73, but on the expense side also included are seven issues of the *Journal*, including Part II of the November issue for which AAEA should be reimbursed.

The amount for regular dues was down due primarily to the way A.I.D. pays and the accounting system. The income from subscriptions was up because special effort was made to contact former subscribers encouraging renewal. We provided back copies of the *Journal* for previous years, for which we collected several thousand dollars, and, hopefully, these people will become regular subscribers.

Journal sales were up primarily due to USDA purchase of Part II of the November issue and Canadian purchase of the December 1978 issue. Income from page charges is up but becoming harder to collect. The investment income is up, thanks to the high interest rates and the careful watch on

Table 1. Number of Members and Subscribers, 1979, with Comparisons

Category	1972	1973	1974	1975	1976	1977	1978	1979
Institutional members	25	20	22	25	26	36	32	34
Regular members–U.S.	2,802	2,504	2,756	2,779	2,731	2,976	2,884	2,865
Foreign	601	487	480	503	766	809	811	870
Senior members[a]	0	0	0	0	47	98	137	140
Junior members–U.S.	398	316	338	484	483	482	462	500
Foreign	38	161	68	66	49	41	47	52
Corresponding[b]–U.S.	0	0	1	2	0	0	0	0
Foreign	82	184	198	207	0	0	0	0
Libraries & Businesses–U.S.	647	635	667	670	572	725	670	739
Foreign	1,196	1,168	1,242	1,227	1,164	1,245	1,271	1,335
Exchange	2	3	3	3	3	3	3	3
Total	5,791	5,478	5,775	5,966	5,841	6,415	6,317	6,538

[a] New, category established in 1976.
[b] Category combined with regular members in 1976.

Table 2. Number of Members Paid by 1 April, Ballots Mailed and Returned with Comparisons

Category	1974	1975	1976	1977	1978	1979	1980
U.S. members	2,401	2,746	2,878	2,721	2,756	2,955	3,192
Canadian members	178	156	175	170	157	154	195
Foreign members	248	592	443	452	440	535	505
Total ballots mailed	2,827	3,494	3,496	3,343	3,353	3,644	3,892
Total ballots returned	1,920	1,850	1,624	1,751	1,712	1,804	1,871

Table 3. 1979 AAEA Operating Statement, with Comparisons, 1975–79

Item	1975	1976	1977	1978	1979
Income			($)		
Dues and subscriptions:					
Regular members	55,545.54	87,951.61	98,894.27	100,103.27	90,203.27
Senior members	0	537.50	799.50	825.00	687.50
Junior members	4,295.14	8,294.28	7,704.73	8,116.54	9,958.64
Subscriptions	39,531.64	56,534.56	49,278.74	56,241.25	74,516.28
Corresponding	1,940.00	3,540.00	0	0	0
Institutional	2,500.00	2,600.00	3,600.00	3,200.00	3,400.00
Lit. Retrieval	3,283.56	0	0	0	0
Journal publications:					
Journal sales	5,714.20	5,156.00	9,405.75	7,815.89	16,834.07
Page charges and reprints	9,575.50	26,700.50	31,294.55	36,022.73	52,240.75
Advertisements (*Journal*)	824.80	1,375.50	327.75	1,195.82	1,035.00
Newsletter	0	0	0	0	2,570.00
Royalties	979.80	557.77	1,325.68	4,260.38	337.13
Other	184.61	0	0	0	0
Postwar Lit. Rev. sales	0	569.00	9,582.00	13,727.50	6,153.59
Investments	9,040.60	9,535.75	12,307.89	16,777.52	28,788.95
Annual meeting	269.80	710.27	1,369.34	2,000.00	8,647.34
Address labels	557.96	1,215.92	1,590.56	1,140.88	1,890.56
Miscellaneous	278.84	223.00	427.13	2,643.39	5,822.37
San Diego	0	0	26,407.30	0	0
Gain (loss) stock sales	0	0	0	21,120.54	29,050.73
Total	134,521.99	205,501.66	254,315.19	275,190.71	332,136.18
Expenses					
Journal:					
Printing	79,324.15	95,703.42[a]	88,733.15[b]	71,543.25[c]	113,359.12[d]
Editorial support	17,700.00	20,000.00	30,000.00	22,500.00	24,500.00
Printing reprints	2,285.23	2,892.23	6,045.11	5,818.22	7,649.88
Purchase *Journal*	323.90	165.00	147.00	98.08	78.00
Newsletter	0	0	0	670.00	9,455.32
Lit. Retrieval Doc. Center	18,862.22	13,942.20	15,000.00	15,000.00	15,000.00
Postwar Lit. Review	0	15,207.76	8,410.50	14,754.70	3,598.50
AAEA (int. conf.) grant	0	5,000.00	0	0	0
Handbook-Directory	0	2,794.04	0	0	0
Awards	1,500.00	1,500.00	1,500.00	1,108.68	1,767.00
Student activities	0	0	0	0	0
General operations:					
Postage and phone	3,879.52	4,465.89	4,611.27	4,140.97	4,359.65
Off. supplies and printing	4,330.22	2,811.80	6,532.83	8,586.15	6,038.81
Annual meeting	1,712.94	1,270.88	2,814.24	5,250.92	1,981.73
Committees	460.27	1,211.38	1,040.52	488.29	61.22
Bonds	149.00	149.00	115.00	115.00	115.00
Audit	400.00	500.00	500.00	500.00	500.00
Secretary-treasurer assistant	14,000.83	15,727.81	20,750.03	17,338.04	17,368.98
Secretary-treasurer honorarium	4,000.00	4,000.00	4,000.00	5,000.00	5,000.00
Miscellaneous	849.66	810.30	791.62	13,383.79	6,702.26
San Diego	0	0	14,706.92	0	0
Total expenses	149,777.94	188,151.71	205,698.19	186,296.09	217,535.47
Balance	−15,255.95	17,349.95	48,617.00	88,894.62	114,600.71

[a] For six (6) issues of the *Journal*.
[b] For five (5) issues of the *Journal* and *Handbook-Directory*.
[c] For four (4) issues.
[d] For seven (7) issues, including Parts I and II of November 1979.

cash flow. We have a nice little income from the sale of address labels.

While the actual income exceeded by a wide margin the estimate when the budget was prepared, the expenses were about as expected. Compared to last year, the biggest increase in the outlay was for seven issues of the *Journal*. The *Newsletter* for 1979 cost $9,455.32 plus some other costs incurred by my office, but it produced an advertising income of $2,570.00. It was likely that some of this income

is the opportunity to work closely with the Board, a dedicated and impressive group.

It has been a pleasure working with Jim Houck in the transfer of the editorship. He has not only taken my advice, but also my assistant editor! My best wishes to him and his associates at the University of Minnesota.

At the top of my thank-you list must be Stan Johnson, who did a lion's share of the work; Herb Stoevener, who did a great job as Book Review Editor; and our right-hand assistants, Marti Luzader and Donna Taylor. I appreciated the many behind-the-scenes contributions of our Secretary-Treasurer, John Redman, to the publishing and distributing of the *Journal*. My thanks also go to an understanding department chairman, Charles Cramer, and to the Editorial Council. Finally, I extend my utmost appreciation to the many reviewers whose unselfish efforts helped to make this year's *Journal*.

V. James Rhodes, editor

Reviewers, 1979–80

John C. Abbott
Philip C. Abbott
Dale W. Adams
Richard M. Adams
Chris M. Alaouze
David J. Allee
Habib Amamou
Glenn Ames
F. J. Anderson
Jock R. Anderson
Lee Anderson
Robert C. Anderson
Kurt R. Anschel
David Arnold
Chester B. Baker
Malcolm D. Bale
Jack Barbash
Pranab K. Bardhan
B. Bruce Bare
John L. Baritelle
Randolph Barker
Paul W. Barkley
Wallace Barr
Peter J. Barry
R. B. Bartholomew
C. Phillip Baumel
Harry S. Baumes, Jr.
Frederick W. Bell
Lloyd D. Bender
Carlos A. Benito
David A. Bessler
Surjit S. Bhalla
Arlo W. Biere
James K. Binkley
Hans P. Binswanger
Richard C. Bishop
Larry L. Bitney
Gordon E. Bivens
Leo V. Blakley
David Blandford
Nancy Bockstael
Michael D. Boehlje
Robert W. Bohall
James T. Bonnen
Wayne A. Boutwell
Garnett L. Bradford
John R. Brake
Jon A. Brandt
Russell Brannon
Maury E. Bredahl
Harold F. Breimyer
Ray F. Brokken
Daniel W. Bromley
Gardner Brown, Jr.
Thomas G. Brown
W. Keith Bryant
Steven T. Buccola
Dan Buckner
Arvin R. Bunker
Harlan Burnstein
Oscar R. Burt
Rueben C. Buse
Walter R. Butcher
Boyd M. Buxton
Gerald R. Campbell
Gerald A. Carlson
George L. Casler
Robert G. Chambers
Hui-shyong Chang
E. D. Chastain, Jr.
Jean-Paul Chavas
Wayne Chow
Thomas S. Clevenger
Willard W. Cochrane
Keith J. Collins
Larry J. Connor
Hugh L. Cook
Melvin L. Cotner
Richard J. Crom
Richard T. Crowder
William H. Crown
Ronald G. Cummings
Dana G. Dalrymple
Leon E. Danielson
Richard H. Day
Carleton C. Dennis
Gary T. Devino
John L. Dillon
Gerald A. Doeksen
Otto C. Doering
John P. Doll
Gordon Donald
M. H. Doran
Peter Dorner
J. Kamal Dow
James L. Driscoll
Marvin R. Duncan
Bobby R. Eddleman
Clark Edwards
Alvin C. Egbert
Carl K. Eicher
Vernon R. Eidman
Donald J. Epp
Bernard Erven
Robert Evenson
Kenneth R. Farrell
Paul R. Farris
Robert S. Firch
Lee Fletcher
Olan D. Forker
John R. Franzmann
A. M. Freeman, III
Ben C. French
R. J. Freund
Jerry E. Fruin
Earl I. Fuller
Stephen W. Fuller
B. Delworth Gardner
Bruce L. Gardner
John O. Gerald
J. P. Gittinger
Joseph B. Goodwin
Richard Green
Michael J. Greenwood
Verner N. Grise
Antonio Guccione
Steven R. Guebert
Russell L. Gum
Duane Hacklander
Josef Hadar
Harry H. Hall
Milton C. Hallberg
Albert N. Halter
Jerome W. Hammond
W. Michael Hanemann
Emil B. Haney, Jr.
Charles B. Hanrahan
J. B. Hardaker
Ian W. Hardie
William E. Hardy
Neil E. Harl
Floyd Harmston
Duane G. Harris
Thomas Harris
Alan Harrison
Kelly Harrison
Stephen B. Harsh
Zuhair A. Hassan
Murray H. Hawkins
Peter B. R. Hazell
Earl O. Heady
Dale M. Heien
Richard G. Heifner
Norlin A. Hein
Larry J. Held
John D. Helmberger
Peter G. Helmberger
William McD. Herr
R. James Hildreth
R. Carter Hill
Labh Hira
Fred J. Hitzhusen
Irving Hoch
George Hoffman
David W. Holland
James P. Houck
Hendrik S. Houthakker
Richard E. Howitt
Wallace Huffman
John E. Ikerd
P. C. Ip
George D. Irwin
James T. Jacobs
Harald Jensen
Glenn Johnson
Paul R. Johnson
Bruce F. Johnston
Richard E. Just
Kandice Kahl
David Kamerschen
Donald C. Keenan
Earl W. Kehrberg
Gordon A. King
Robert P. King
Henry Kinnucan
Yoav Kislev
Robert W. Klepper
Darrel D. Kletke
James B. Kliebenstein
Jack L. Knetsch
Glenn J. Knowles
William E. Kost
Ronald D. Krenz
Wesley R. Kriebel
John Kuehn
John Kuhlman
John Kushman
Walter C. Labys
George W. Ladd
F. Charles Lampear
Sylvia Lane
Max R. Langham
Donald K. Larson
Paul Laslay
Ralph G. Lattimore
David Lee
Warren F. Lee
E. Phillip LeVeen
Raymond M. Leuthold
Donald R. Levi
David S. H. Liao
Peter Liapis
Lawrence H. Libby
Robert K. Lindner
David A. Lins
Charles Y. Liu
Heraclio A. Lombardo
T. Gordon MacAulay
Lawrence E. Mack
J. Patrick Madden
Wilbur R. Maki
Alden C. Manchester
Lester V. Manderscheid
Harry P. Mapp, Jr.
Bruce W. Marion
James Marsden
Katherine Marshall
Neil R. Martin
Philip L. Martin
William E. Martin
Robert J. Marty
Robert T. Masson
Loys L. Mather
Stephen F. Matthews
Scott C. Matulich
Alex F. McCalla
Bruce A. McCarl
Francis McCamley
Kenneth E. McConnell
James W. McFarland
William L. McKillop
John R. McNamara
Yash P. Mehra
Karl D. Meilke

James Melvin
Robert Mendelson
Stephen E. Miller
Thomas A. Miller
Larry C. Morgan
Timothy D. Mount
Willard F. Mueller
Ramesh Munankami
Yiar Mundlak
John C. Nash
Glenn L. Nelson
Kenneth Nelson
John P. Nichols
John Noller
Carl W. O'Connor
Ronald A. Oliveira
Fred L. Olson
Dale K. Osborne
Donald D. Osburn
Jack W. Osman
Don Paarlberg
Philip Paarlberg
Daniel I. Padberg
Emilio Pagoulatos
A. Parikh
Quirino Paris
E. C. Pasour, Jr.
Allen B. Paul
Arnold Paulsen
Anne E. Peck
J. B. Penn
John B. Penson
Richard K. Perrin
R. D. Peterson
Willis J. Peterson
Michel J. Petit
Per Pinstrup-Andersen
Gerald Plato
James S. Plaxico
Leo Polopolus
Rulon D. Pope
Wilfried Prewo
David W. Price
Michael Price
Fred J. Prochaska
Giles T. Rafsnider
Alan J. Randall
Philip M. Raup
Gordon C. Rausser
Michael R. Reed
Katherine Reichelderfer
Robert D. Reinsel
Joseph J. Richter
Kenneth L. Robinson
Lindon J. Robison
Terry Roe
George Rogers
James A. Roumasset
Clifford S. Russell
Vernon W. Ruttan
Mary E. Ryan
Michael Ryan
John H. Sanders, Jr.
Alexander Sarris
Pasquale L. Scandizzo
Herbert Scarf
Gerald E. Schluter
Stephen C. Schmidt
Andrew Schmitz
Kenneth Schneeberger
Roger E. Schneider
Richard A. Schoney
David M. Schoonover
Lee F. Schrader
Dean Schreiner
Ronald A. Schrimper
Leonard A. Schruben
G. Edward Schuh
Bryan Schurle
Grant M. Scobie
Helen J. Scott
John T. Scott, Jr.
David Seckler
Wesley D. Seitz
Alan K. Severn
J. Scott Shonkwiler
C. Richard Shumway
Surjit S. Sidhu
Inderjit Singh
Rudie W. Slaughter
Eldon D. Smith
V. Kerry Smith
Milton D. Snodgrass
L. Orlo Sorenson
Stephen H. Sosnick
Thomas L. Sporleder
Thomas H. Spreen
U. K. Srivastava
Thomas H. Stafford
Charles W. Stahl
M. S. Stauber
Robert Stern
Thomas Stout
Ivar Strand
Roger W. Strohbehn
Daniel Suits
Gurushri Swamy
Earl R. Swanson
Alan Swinbank
Takashi Takayama
C. Robert Taylor
Gary C. Taylor
Lester D. Taylor
William C. Thiesenhusen
Robert L. Thompson
Stanley R. Thompson
Erik Thorbecke
Marie Thursby
Ronald L. Tinnermeier
William G. Tomek
Randall E. Torgerson
Bruce Traill
Ronald L. Trosper
Luther G. Tweeten
Wallace E. Tyner
Joseph N. Uhl
William J. Vaughan
J. D. Von Pischke
T. D. Wallace
Ronald W. Ward
T. K. Warley
Philip F. Warnken
Robert D. Weaver
Paul Webster
Delane E. Welsch
Donald A. West
Jerry G. West
Randall E. Westgren
Morris D. Whitaker
Fred C. White
James K. Whittaker
Norman K. Whittlesey
Lawrence Witt
Abner Womack
Roger C. Woodworth
Gene Wunderlich
Dan Yaron
Douglas Young
Robert A. Young
Anthony C. Zwart

Report of the Awards Committee

Distinguished Extension Programs

Less than ten years' experience. **James C. Cato,** University of Florida.
More than ten years' experience. **Paul R. Robbins,** Purdue University.

Distinguished Policy Contribution

Bruce W. Marion, executive director, USDA and University of Wisconsin. "Organization and Control of U.S. Food Production and Distribution Systems.

Distinguished Undergraduate Teaching

Less than ten years' experience. **Ronald J. Hanson,** University of Nebraska.
More than ten years' experience. **Robert W. Taylor,** Purdue University.

Outstanding Doctoral Thesis

Oral Capps, Jr. "The Impact of Selected Nonfoods, Foods, Socioeconomic, and Demographic Characteristics on the Decision to Purchase Various Meats and Seafoods for Home Consumption." Virginia Polytechnic Institute and State University (adviser: Joseph Havlicek, Jr.).
Donald Allan Johnson. "Investment, Production, and Marketing Strategies for an Iowa Farmer-Cattle Feeder in a Risky Environment." Iowa State University (adviser: Michael D. Boehlje).
David Fergus Nygaard. "Risk and Allocative Errors Due to Imperfect Information: The Impact on Wheat Technology in Tunisia." University of Minnesota (adviser: Terry Roe).
Honorable mention: Reinaldo Ignacio Adams. "Agricultural Adjustments to Brazil's Alcohol Program—A Regional Economic Analysis." Ohio State University (adviser: Norman Rask).
Honorable mention: Bartelt Eleveld. "The Impact of Increasing Input Prices on the U.S. Farm Sector: A

Dynamic Simulation Approach." Texas A&M University (advisers: Bruce R. Beattie and John B. Penson, Jr.).
Honorable mention: Timothy Jay Tyrrell. "An Application of the Multinomial Logit Model to Predicting the Pattern of Food and Other Household Expenditures in the Northeastern United States." Cornell University (adviser: Timothy D. Mount).

Outstanding Master's Thesis

John MacIntosh Calloway, Jr. "The Optimal Use of Surface Water with Return Flows Present: A Theoretical Model for Deriving Alternative Allocation Rules." University of Minnesota (adviser: Wilbur R. Maki).
Manuel Sanchez. "Updating Methods for Adaptive Econometric Models." University of Missouri (adviser: Stanley R. Johnson).
Robert N. Stavins. "Forecasting the Size Distribution of Farms: A Methodological Analysis of the Diary Industry in New York State." Cornell University (adviser: Kenneth L. Robinson).
Honorable mention: Karlene Hertel. "An Economic and Statistical Analysis of Pecan Prices." Texas A&M University (Carl E. Shafer).
Honorable mention: Lawrence D. McKinzie, III. "An Econometric Model of the Canadian Wheat Market." Purdue University (adviser: John D. Spriggs).

Quality of Research Discovery

Bruce L. Gardner. *Optimal Stockpiling of Grain.* Lexington, Mass.: Lexington Books, 1979.
Yair Mundlak. *Intersectoral Factor Mobility and Agricultural Growth.* Washington, D.C.: International Food Policy Research Institute, Feb. 1979.
Honorable mention: Willard W. Cochrane. *The Development of American Agriculture: A Historical Analysis.* Minneapolis: University of Minnesota Press, 1979.
Honorable mention: Gordon C. Rausser and Elthan Hochman. *Dynamic Agricultural Systems: Economic Prediction and Control.* New York: North-Holland Publishing Co., 1979.

Quality of Communication

Gail L. Cramer and Clarence W. Jensen. *Agricultural Economics and Agribusiness: An Introduction.* New York: John Wiley & Sons, 1979.
Lowell D. Hill, Marvin R. Paulsen, and Margaret D. Early. *Corn Quality: Changes During Export.* Illinois Agr. Exp. Sta. Special Pub. 58, Sep. 1979.
Honorable mention: Richard Beck, Ronald R. Canham, Ronald C. Faas, Bruce Florea, George Goldman, Robert E. Howell, Eugene Lewis, Garnet Premer, Neil R. Rimbey, Theodore R. Siegler, Bruce Weber, and **Russell C. Youmans.** *Coping with Growth.* Corvallis, Ore.: Western Rural Development Center, WREP 16–17 and 20–26, 1979.
Honorable mention: Jack H. Armstrong, E. M. Babb, John A. Barton, Calvin L. Beale, Eric Bjornlund, William T. Boehm, Robert Bohall, Robert F. Boxley, C. E. Bray, David Brewster, David L. Brown, Thomas A. Carlin, Anne Marie del Castillo, George W. Coffman, John M. Connor, John R. Dunn, Milton H. Ericksen, Dwight Gadsby, Linda M. Ghelfi, Tom Hady, L. G. Hamm, David H. Harrington, James S. Holt, Bruce Hottel, Gene Ingalsbe, James D. Johnson, Max Jordan, David A. Lins, Yao-Chi Liu, Thomas J. Lutton, Richard Magleby, Ronald L. Meekhof, Thomas A. Miller, Allen B. Paul, J. B. Penn, Donn Reimund, Robert D. Reinsel, Lyle P. Schertz, Jerry A. Sharples, Harold Stults, William G. Tomek, Donald L. Van Dyne, and **Larry Walker.** *Structure Issues of American Agriculture.* USDA ESCS Agr. Econ. Rep. 438, 1979.

Publication of Enduring Quality

Earl O. Heady and John L. Dillon. *Agricultural Production Functions.* Ames: Iowa State University Press, 1961.

Outstanding Journal Article

George W. Ladd. "Artistic Research Tools for Scientific Minds." *Amer. J. Agr. Econ.* 61(1979): 1–11.

Daniel I. Padberg, chairman

Minutes

Minutes of the Executive Board Meeting, Chicago

The meeting was called to order by President Stanton at 8:30 a.m., 18 January 1979.

Present: Voting members:
Stanton, Hildreth, King, Coffey, Brown, Crowder, Lane, Schuh, Hopkin
Members ex officio:
Redman, Rhodes
Guests:
Loomis, Barr, Connor

1. Stanton reviewed the agenda to be followed during the next two days.

2. Lane moved the approval of the minutes of the Executive Board meeting held at Blacksburg, Virginia, on 5–6 August 1978. Seconded. Passed.

3. Redman, as secretary-treasurer presented a preliminary report on income and expenditures as well as membership statistics for 1978, indicating that results were fairly consistent with the budget. Lane moved acceptance of the report. Seconded. Passed.

4. Rhodes reported as editor, indicating that the total cost for the 1978 *Journal* will be within the budget; the *Journal* is on schedule; authors have paid the page charge for about 88% of the pages; and he presented some concerns associated with *Journal* content. He presented Board with advance copies of the *AAEA Newsletter*, a new activity of the Association. Approximately 6,500 copies were printed to be sent initially to all members and subscribers. Rhodes is to report at the summer meeting on problems and experiences with the Newsletter and, if needed, an advisory committee will be appointed. Crowder moved acceptance of the report. Seconded. Passed.

5. Redman reported for an ad hoc committee to explore the copyright issue. Redman gave a brief summary of the material he prepared on copyrighting the *Journal*. Harl, as our attorney, had received the material but had not had time to offer comments. It was recommended that (*a*) a form be developed to obtain all rights from the author and his employer; (*b*) use the notice "copyright 19____ by the American Agricultural Economics Association" at the bottom of the title page of each article; (*c*) since the AAEA would own all rights, permission for reproduction by professors, libraries, and nonprofit agencies be given liberally up to specified limits; and (*d*) members of AAEA be made aware of copyright restrictions. Lane moved that the *AJAE* place on the title page of each article the notice "Copyrighted 19____ by the American Agricultural Economics Association." Seconded. Motion lost. It was suggested that the committee continue its study of the copyright issue, secure an opinion from our attorney, and report again with recommendations at the 1979 summer meeting.

6. Stanton reviewed the plans for the 1979 summer meeting. The invited paper sessions are well organized. Nerlove was selected by the Board from a number of suggestions to give the Kellogg lecture. Loomis, chairman of local arrangements for 1979 summer meeting, reported on plans made, proposed budget, etc. Brown moved that the registration fee be $20.00 for singles and $25.00 for families. Seconded. Passed.

Hildreth moved that any surplus which may result from the registration fees after meeting all expenses be divided on a 50–50 basis and any loss be sustained by the AAEA. Seconded. Passed.

Hopkin moved that the registration fee for undergraduates be set at $5.00. Seconded. Passed.

7. Each year the AAEA has the opportunity to make a nomination for the Browning award. Since the AAEA's nominee won the award last year, the special committee chaired by Breimyer recommended that AAEA wait until 1980 to make a nomination. Crowder moved that AAEA not make a nomination this year. Seconded. Passed.

8. Conner reported as chairman of an ad hoc committee on CAST, giving general description of purposes, organization, operation, financing of its activities, and the possible costs and benefits involved in membership. Crowder moved that an ad hoc CAST committee report and a questionnaire be sent to the membership under the President's signature asking that the questionnaire be returned to the chairman of the ad hoc CAST committee by a given date for analysis and pointing out that a vote will be taken at the time of the annual meeting on whether AAEA will join CAST. Seconded. Passed. The statement and questionnaire are to be sent via "permit mail" to North American members as soon as possible.

9. Sundquist reported as chairman of the Management, Structure, Methods, and Procedures Committee, listing the major issues surfaced from the study as follows: (*a*) Any modification in organization and management of AAEA which weakens the broad base of participation by members in policy making, activity planning and programming would be viewed with disfavor. (*b*) Other than bylaws, there is little currently available in the way of formal position descriptions, identification of responsibilities, and specification of operating procedures for officers, board members, and committees. (*c*) Keen interest and strong performance by individual officers, board members, and committee chairpersons is crucial to AAEA, with its broad-based committee structure and high turnover of individuals in positions of responsibility. (*d*) An ac-

cessible, up-to-date data base of AAEA membership is a key "missing ingredient" for effective planning and management for a broad set of current and potential activities. (*e*) Some restructuring of management responsibilities in AAEA policy making, program planning, and implementation might be needed in order to reduce the workload of the president. (*f*) The changing from the present organization to one that includes an executive office raises sub-issues of additional cost, the possibility of the director unsurping the current broad decision-making involvements of AAEA members, and the felt need to move in direction of a central administrative office to reduce the heavy workloads and subsidizations currently inherent in the offices of the president and secretary-treasurer and to undergird the provision of more effective current services and additional programming for numerous special interests. King moved that AAEA affirm items (*a*), (*b*), and (*c*) above. Seconded. Passed.

Crowder moved that AAEA adopt the recommendation to continue and strengthen the current practice of assigning responsibilities to individual members of Board to design, monitor, and manage the programmatic, financial, and administrative activities of AAEA. Appropriate mechanisms for accountability should be developed and implemented. Seconded. Passed.

Crowder moved that AAEA adopt the recommendation that a task force be established immediately consisting of the immediate past president and the president-elect, augmented by not more than two additional members, to develop operational position descriptions for the Association's president-elect, president and immediate past president with the objective to outline a three-year sequence of responsibilities to spread more evenly the workload of the AAEA presidency so more attention can be given to policy planning and innovative programming. Seconded. Passed.

Crowder moved that the recommendation be adopted to establish immediately a small working task force to specify an operational data base, needed for use in the effective management and programming activities of AAEA, to estimate the cost of developing and maintaining the data base and to specify specific steps needed to implement the operation. Seconded. Passed.

Crowder moved to table the recommendation that a task force be appointed immediately, consisting of both current members of the board and other members to plan the establishment of an executive office for the Association to be operational by no later than 1983 and to be located in either Washington or Chicago. Motion died for lack of second. Hildreth moved that the recommendation be an item on the agenda for the summer 1979 board meeting. Seconded. Passed.

10. Barr reported for the committee to establish a position description and list of responsibilities for the office of secretary-treasurer. Lane moved the adoption of the report and it be made a part of the bylaws as Section I, entitled "Organization and Operation of the Office of the Secretary-Treasurer." Seconded. Passed.

11. Bromley sent a statement concerning a recommendation and procedures concerning sponsorship of conferences and symposia. The AAEA should actively seek proposals prepared according to prescribed guidelines. These will be evaluated by the Professional Activities Committee and a recommendation made to the Board for final action. Lane moved the approval of the statement and its incorporation in the statement of Board policy. Seconded. Passed.

12. Hildreth reviewed the recommendations on the proposal for establishing a special committee on large models of the agricultural sector. After discussion, Hildreth moved that the recommendation be adopted. Seconded. Passed.

13. The report by Meenen on evaluation of annual meetings was discussed. It was the consensus that the chairmen of the various sessions at the 1979 meeting should be asked to evaluate their sessions according to criteria to be supplied to each chairman by those establishing each of the major sections of the program.

14. Redman presented a letter from Cal Conner and an accompanying report covering the 1978 summer meeting at Blacksburg. The meeting produced a surplus of $8,838.79 of which 60%, or $5,302.27, reverted to the AAEA. Hopkin moved acceptance of the report with appreciation to the Department at VPI. Seconded. Passed.

15. Coffey reported for the portfolio subcommittee of the Finance Committee. The recommendations were to (*a*) convert all AT&T preferred to common stock; (*b*) sell 200 shares of Texaco October options at about 26; (*c*) purchase $15,000 of Farm Credit 6-month bonds; (*d*) purchase $15,000 of Farm Credit 9-month certificates; (*e*) purchase 300 shares of American Home Products at about $28 or 400 shares of Continental Corporation at about $24–$25. Lane moved acceptance of recommendation (*a*) and (*b*) and moved that $25,000 of short-term obligations of six to nine months be purchased. Seconded. Passed.

Crowder moved that 200 shares of American Home Products be purchased at about $28 or better, with a stop placed at about $25. Seconded. Passed. He suggested that all of AAEA issues be studied by the Finance Committee with the idea of placing stops on each issue.

Hildreth moved to authorize the secretary-treasurer to place short-term funds not needed for operations into money market funds or passbook savings accounts with the criteria for choice to be the rate of return. Seconded. Passed.

16. Lane presented a proposal for rewording the criteria for eligibility for outstanding Ph.D. and M.S. degree program awards. After considerable discussion, no action was taken. Lane agreed to

work with the Awards Committees to redraft these criteria again.

17. Lee Martin sent a status report on the sales of volumes 1 and 2 of the *Postwar Literature Review*. A total of 1,444 copies of volume 1 and 1,009 copies of volume 2 have been sold. Martin expects volume 3 to be ready by end of 1979.

18. Stanton reported that an extension of the USDL contract had been requested to 30 September 1979, with no change in amount of funds required. Completing the contract by that date is strongly encouraged.

19. Coffey presented the plan to be followed in evaluating and obtaining proposals for the *Journal* printing contract. Bids will be sought from four or five printing firms and will be evaluated from both monetary and nonmonetary standpoints.

20. Hildreth reviewed the possible future sites and invitations for AAEA annual meetings. After discussion, Lane moved that AAEA accept the invitation to meet on the campus of Clemson University 26–29 July 1981. Seconded. Passed.

Lane moved that AAEA accept the invitation to meet at Utah State University during the last week of July or first week of August 1982. Seconded. Passed.

21. Hildreth reported on the symposium on food regulation jointly sponsored by ESCS, Farm Foundation, and AAEA. It was proposed that USDA publish the papers from the proceedings in a special issue of *AJAE* with ESCS covering the costs. It was agreed that USDA and AAEA should proceed to work out the details on publication, with the privilege of veto by the president and editor.

22. Hildreth presented an updated set of Bylaws as well as an up-to-date statement of policies of the Board. Lane moved the approval. Seconded. Passed.

23. Stanton reported on a request from Science and Education Administration (SEA) seeking suggestions of high priority problem areas deserving further study and analysis. Five problem areas selected were (*a*) identifying sources of agricultural productivity, (*b*) establishing new criteria for evaluating agricultural research, (*c*) emphasizing the economics of human nutrition, (*d*) improving the efficiency of transport in food industry, and (*e*) understanding the impact on rural communities of migration to and from urban and suburban areas. Each issue is to be described with 100 words or less and sent to the director of SEA by the AAEA president.

24. Crowder commented on current budget allocations to individual activities of AAEA, raising questions on what would have been the result if different allocations had been made and encouraged use of the opportunity cost principle in considering alternatives.

25. The Executive Board went into executive session to review the nomination for Fellows and make the selection of those to be presented to the Fellows Election Committee to be elected as Fellows.

26. Board adjourned at 1:30 a.m., 19 January 1979.

Respectfully submitted,
John C. Redman
Secretary-Treasurer

(These minutes were inadvertently omitted from the 1979 Proceedings.)

Minutes of the Executive Board Meeting, Atlanta

The meeting was called to order by President King at 1:00 p.m., 27 December 1979.

Present: Voting members:
King, Stanton, Tweeten, Brown, Coffey, Dennis, Harl, Hopkin, Schuh
Members ex officio:
Redman, Rhodes, Colyer
Guests:
Padberg, Halcrow

1. King reviewed the agenda and obtained its approval.

2. Local arrangements for the Allied Social Sciences Association meeting were reviewed briefly. All sessions sponsored by AAEA will be held at the Hyatt-Regency including the reception-cash bar for AAEA members on 28 December.

3. Stanton moved the approval of the minutes of the Board meetings at Washington State as distributed. Seconded. Passed.

4. Secretary-Treasurer Redman reported that membership for 1979 was the largest in history, with 6,538 in all categories, a net increase of 221 over 1978. The Association's cash-flow position was strong. He indicated the likelihood of a substantial positive balance for the year when the books are finally closed. No specific balances could be presented because the year was not yet completed.

5. Editor Rhodes reported for operations with respect to the *Journal* and *AAEA Newsletter*. For the year December 1978–November 1979, the *AJAE* published 1,288 pages, at an average cost of $65 per page plus some additional charges for mailing billed directly to Redman's office. He concluded the *Journal*'s costs were within budgeted estimates. Page charges had been collected on 84% of those to which they had been billed compared to 88% in the previous year.

The Newsletter has been well received. There has been a problem of including all the material proposed within sixteen pages on a bimonthly basis. The Board agreed that the current format should be continued.

Editor Rhodes reported that 17 of the 100 contributed papers presented at Pullman, Washington,

had so far been submitted for review as notes or articles.

6. The proposal from Johnson Associates to obtain a nonexclusive agreement from AAEA to microfiche the *AJAE* was discussed. No formal action was taken, given our continuing relationship with University Microfilms.

7. Halcrow as arrangements chairman presented the plans for the summer meeting of the Association at the University of Illinois, Champaign-Urbana. The proposed budget was reviewed. It was moved, seconded, and carried that registration fees be set as follows: Member \$30, student \$15, member's spouse \$10, all children in one family \$7, nonmember \$55 (\$25 for AAEA membership), nonmember undergraduate and graduate student \$27.50 (\$12.50 for AAEA membership). AAEA guaranteed 1,000 member registrations to the University of Illinois to cover basic costs. Illinois will impose a late registration fee of \$20 for members and \$10 for students after 15 June. Refunds of registration fees in full will be made to registrants if requested by 15 August 1980. Other details of facilities available and costs were discussed. Refunds on banquets and dormitory fees will be made if requested by 15 July. The budget and tour schedule was approved as presented after substantial discussion.

8. Announcements for the Selected Papers (Contributed Papers) and Organized Symposia were distributed by President King. These were approved and will appear in the January 1980 Newsletter. Mitchell and Watt will serve as co-chairmen of the Selected Papers Committee. Proposals for symposia will be sent to President King for review by him, the president-elect and past president. Tweeten reviewed the progress in the development of the Invited Paper sessions chosen by Executive Board at the program planning meeting held at Urbana, Illinois, 13 November 1979.

9. Schuh, chairman of the ad hoc committee to solicit nominations for a new editor, reported. Six proposals were received and briefly reviewed. After discussing the criteria used for evaluating the proposals received, the committee recommended further consideration of three of the nominations by the Board as a whole. All three proposals received substantial discussion. A secret ballot was taken and the proposal from the University of Minnesota with James Houck as editor assisted by Sexauer, Eidman, and Smith was selected and approved.

10. Coffey reported for the Finance Committee and distributed an eight-page written report including projection of income and expense for 1979, and updating the events affecting the 1980 budget since the budget was passed in July 1979. It was projected that AAEA will have a surplus of approximately \$25,000 for 1979. (Later, after the books were closed, surplus was \$115,000).

A statement on portfolio holdings distributed by Redman was reviewed. After the July Board meeting the following actions recommended by the Portfolio Subcommittee were taken: (*a*) 5 October 1979, 300 shares of CIT were sold at \$60 per share; (*b*) 10 October 1979, 400 shares of Standard Oil of Indiana sold @ 71-¼; (*c*) 9 October 1979, 400 shares of Continental Corporation were purchased @ 25; (*d*) 10 October 1979, 400 shares of Foremost-McKesson were purchased @ 25, 300 shares of Southern Pacific purchased @ 33-¾, 400 shares of Gerard purchased @ 26-½, 200 shares of MMM purchased @ 52-⅜; (*e*) 1 November 1979, purchased \$40,000 Federal Farm Credit Bank's 9-month bond yielding 14.35% interest.

No new transactions or changes in the portfolio were recommended to the Board by the Subcommittee on Portfolio, chaired by Brake, with Feltner and Redman as other members.

The Finance Committee recommended to the Board a new wording on its policy with respect to stop-loss orders, and actions to be taken by the Portfolio Subcommittee between Board meetings. After substantial discussion of the new proposal in comparison with the existing policy, the proposal was withdrawn by Coffey for further review by the committee and discussion at the next Board meeting.

The overall report was accepted with appreciation by the Board for the continuing work of this key committee.

11. Redman presented a proposed time schedule for publication of the next *Handbook-Directory*. No action was taken.

12. Coffey and King reported for the ad hoc committee chaired by John Stoval, which was asked to investigate alternatives for the future location and handling of the business and office operations of AAEA.

Coffey reviewed tentative budgets or costs associated with different methods of operating the Office of Secretary-Treasurer under possible alternatives suggested by the ad hoc committee.

King distributed a letter from Robert Rudd, Chairman of the Department, University of Kentucky, dated 7 December 1979. It proposed that AAEA reimburse the University for time and services rendered to support the Office of the Secretary-Treasurer. In return, the University would make services of Redman available officially on a full-time basis to operate and manage the office of AAEA and to perform other assigned duties, starting 1 July 1980, or sooner if possible, and to continue for a period of five years terminating with his retirement. Kentucky indicated no interest in continuing a part-time commitment on Redman's time, arguing that this was unfair to both Redman and the University.

Redman called the Board's attention to the several pages of job description developed by the Board. He detailed a long list of questions on duties to be performed should the AAEA employ the American Dairy Science Association to manage its

office. He noted also that he had given ten years of personal and enthusiastic service and that the University of Kentucky had permitted him for a number of years to devote virtually full time to do the increasing amount of work efficiently. It was suddenly realized that Redman had experienced a sizable financial penalty for lack of productivity to the University. Both Redman and the University thought this proposal was a fair, equitable, and reasonable way to solve a dilemma.

The Board went into Executive Session to consider the proposal and respond to the Rudd letter. It was moved, seconded, and carried unanimously that the following statement be made:

> The President reported that a communication had been received from the University of Kentucky relative to future arrangements for the office of Secretary-Treasurer. After extended discussion, it was agreed by the Board that, in light of financial considerations and duties of the office as presently defined, it would not be feasible to move to employment of a full-time individual in an executive position with the Association. The President was instructed to so advise the University of Kentucky.
>
> The Board reviewed the efforts to date in evaluating alternatives for the management of financial, accounting, and clerical aspects of Association activity and concluded that further evaluation was needed but that a consensus existed favoring a move toward an off-campus arrangement.

13. The Board continued in Executive Session to consider the report of the Board Advisory Committee on AAEA Fellows nominations. Redman had distributed previously to the Board twenty-two formal nominations that had been received from departments or groups. All nominees from previous years were considered along with a group of names generated by the committee and the Board. By a series of secret ballots, the list was narrowed and eight names were selected and forwarded to the Fellows Election Committee for final decision.

The meeting recessed at 10:00 p.m. and reconvened at 8:30 a.m. 28 December 1979 in the same location.

14. The Professional Activities Committee, chaired by Bromley, prepared a written report which was distributed to the Board. Hopkin led the discussion on its proposals. It was moved by Hopkin, seconded by Harl, and carried that AAEA sponsor the teaching workshop as proposed by the Resident Instruction Committee, entitled "Are You Communicating," and that AAEA allocate $1,000 to support this workshop, with the requirement that a minimum of $600 be allocated for awards to young agricultural economists (including Ph.D. candidates) for registration fees. It will be held at Southern Illinois University the Friday and Saturday preceding the summer meetings at the University of Illinois. Herr from Resident Instruction Committee was present and answered questions about the proposed program. It will be promoted through departments and the *AAEA Newsletter*. King appointed Hopkin to serve as the Board liaison with the workshop. The Board commended the committee for its revised proposal and planning efforts.

The Professional Activities Committee recommended that AAEA cosponsor the Symposium on the Value of Weather Information with the American Meteorological Association in Boston, January 1981, on the recommendation of a special subcommittee chaired by L. Eisgruber. Hopkin moved, seconded, and carried that sponsorship by AAEA be given and that the President appoint a liaison person to work with AMA on the symposium. Hopkin was appointed as Board liaison.

On recommendation of Wally Tyner and his ad hoc committee, Hopkin moved that the AAEA join the American Society of Agricultural Engineers in sponsorship of a National Energy Symposium. Seconded. Passed. Miranowski, of Iowa State, and Doering, of Purdue, were suggested as AAEA liaisons. Schuh was designated as the Board liaison.

15. President King distributed a listing of all committee appointments to the Board. These will be published in the Newsletter as rapidly as possible.

16. Other standing committee reports:

(*a*) No special action was required on an oral report from Economic Statistics given by Hopkin.

(*b*) Mathia sent a report from the Membership Committee. Recruitment is organized on a regional basis. The new brochure has been distributed; special targets for 1980 are graduate students and extension workers.

17. Other special committee reports: Oral briefings or comments were made by Brown with respect to the plans of the Extension Affairs Committee. Chairman Ikerd has already commented to the membership through the Newsletter. A special program effort during 1980 is planned.

Dennis reported that Crowder had activated the Industry Affairs Committee which has met once in Chicago and is planning activities for the summer meetings. Johnson sent a report for the Professional Registries Committee. The changeover to a fully documented program managed and handled by the Illinois State Employment Service has proceeded slowly. President King reported briefly on progress in publishing the final two volumes of the *Postwar Literature Review*, indicating that volume 3 should be available during 1980.

18. AAEA has again been requested by SEA, USDA to provide the Association's suggestions for priority areas for funding in the next USDA budget. The Board responded to a similar request for the first time a year ago in January 1979. It was generally agreed that the Board should respond formally to this initiative as effectively as possible. An open discussion of possible priority items in the areas of research, extension, and instruction was led by President King. Some materials prepared in ad-

vance by Board members were distributed and reviewed. Rather than try to operate as a committee-of-the-whole Schuh was asked to form a subcommittee consisting of Tweeten, Brown, and Harl to develop a set of statements with the help of other Board members. It was agreed that Schuh would summarize these priority statements in the form requested by SEA and present them to Bertrand in written form. If possible, Schuh was encouraged to seek a meeting with the SEA administrator to present these priorities personally and emphasize the need for greater emphasis on social science research and outreach activity. Copies of the final documents were to be distributed subsequently to all Board members.

19. The Board reviewed the invitation from the Department of Agricultural Economics, Cornell University, to host the meetings in Ithaca on 5–8 August 1984. The Board voted unanimously to accept the invitation. This means that the summer meetings will be held in 1981 at Clemson; 1982 at Utah State; 1983 at Purdue; 1984 at Cornell; and 1985 at Iowa State. Redman and Farris were to be asked to explore alternatives should Purdue desire to withdraw.

20. Redman presented the report by Loomis on the results of 1979 annual meeting at Washington State University, and noted that a check for \$2,122.19, representing one-half of the net surplus, had been received. Stanton moved that the report be accepted and again express our gratitude to Loomis and Washington State for an outstanding meeting. Seconded. Passed.

21. King reported that a communication had been received from M. Johnson of North Carolina State proposing that an individual rather than two nominees be presented each year for the office of president-elect. The consensus of the Board was that the membership was firmly on record favoring the present method of paired nominations.

22. Breimyer, Chairman of the Browning Award Committee, reported via letter that documentation for a candidate for the Browning Award would be provided in the near future. His committee suggested that a nominee for the von Humboldt Award not be forwarded this year. The Board concurred and the President agreed to forward to the Board members the supporting information concerning the nominee for the Browning Award when received from Breimyer.

23. Appreciation was extended to Gold Kist, Inc. and Glen Glover for their support of the social hour on 28 December for AAEA members.

The meeting was adjourned at 12:10 p.m.

Respectfully submitted,
John C. Redman
Secretary-Treasurer

Minutes of Special Executive Board Meeting, Atlanta

The special session called by President Richard King met first in an informal session on 10 April 1980, at 7:30 p.m.

Present: Voting members:
King, Coffey, Hopkin, Brown, Stanton, Dennis, Tweeten
Absent: Voting members:
Harl, Schuh (who was present on April 11)
Members ex officio:
Redman
Guests:
Hildreth, Rudd

1. King presented a summary of events leading up to the purpose of the call of the special board meeting and opened the floor for general informal discussion.

2. Rudd reviewed the University of Kentucky proposal which called for AAEA to reimburse the University for time and services rendered to support the office of Secretary-Treasurer, and in return, the University would make services of Redman available officially on a full-time basis to operate and manage the office and perform other assigned duties for a period of five years terminating with his retirement. Discussion followed, including the possibility of a part-time arrangement with Kentucky and AAEA.

3. Stovall presented the report of the Ad Hoc Committee on Establishing an Office for AAEA. It recommended that the Executive Board of AAEA begin negotiations with the American Dairy Science Association to conduct the business and management affairs of AAEA commencing 1 January 1981, at a cost of \$5 per member, or approximately \$35,000 per year.

The committee presented some concerns and issues which the Board should consider. They were:

(*a*) *Loss of control by AAEA*. Turning the business over to another organization might be construed by members as a loss of control and as a threat to the special character of AAEA.

(*b*) *The AJAE*. The Dairy Science Association provides editing and publishing services for several journals. The AAEA will have the option (i) continue the current arrangement with our editor and printer and exclude Dairy Science, (ii) include *AJAE* as a part of the arrangement to be negotiated, or (iii) defer action now and decide at a future date, after a committee has studied the choices and made recommendations. The committee recommended option (iii).

(*c*) *Investment portfolio*. For other associations, Dairy Science handles the investment. The committee recommended that AAEA continue to handle long-term investments but allow Dairy Science to manage the short-term investment and cash-flow requirements.

(*d*) *Handbook-Directory*. The negotiations with Dairy Science should include consideration of a directory and the cost that would be incurred.

(*e*) *Data processing*. It was the belief of the committee that AAEA could benefit from modern computer hardware and software to handle much of our data base and for developing financial reports, accounts, membership lists, etc. The ADSA does not have nor does it plan to obtain such capability. This issue should be discussed fully with ADSA prior to any agreement and that a condition of such agreement be a study of the feasibility of ADSA converting to a computerized system and that AAEA participate in such study.

(*f*) *Duties of AAEA secretary and/or treasurer*. If the agreement with ADSA is consummated, a change would be needed in bylaws specifying the duties of the secretary-treasurer. Most associations affiliated with ADSA continue to have one of their members serve as secretary and/or treasurer whose major duties would be to record the proceedings of meetings of the Board and conduct certain financial or legal transactions. The committee recommended that bylaws be changed to recognize ADSA responsibility for handling the business and management affairs, defining a more limited role for the secretary and that there not be an office of treasurer.

(*g*) *Transition*. It appears that the best time to transfer the office would be at the end of the calendar year, with an audit and accounts transferred as of 1 January 1981. A period of transition would be necessary to phase out operations at the University of Kentucky and to begin at Champaign, Illinois. The ADSA should begin the transition during the fall of 1980 and begin certain functions, such as mailing out notices of dues and the transfer of membership lists to the ADSA system.

The committee suggested a special committee be appointed (composed mainly of Board members) to begin negotiations with ADSA.

4. Redman gave a long and detailed list of tasks, duties, and responsibilities of the secretary-treasurer, which apparently would not be performed by the ADSA. He estimated that ADSA would perform about 30% of the current workload, and raised questions on the desirability of separating the financial and business records from other records of the office.

The Board recessed.

5. The Board reconvened at 8:00 a.m. on 11 April 1980 and went into executive session.

The following action was taken:

It was moved by Coffey, seconded by Schuh, and carried unanimously that the Board reaffirm its decision made 27 December 1980 at Atlanta and reported as Item 12 in the minutes. It was further moved, seconded, and carried unanimously that in light of financial considerations and the duties of the office as presently described, it is not feasible to employ a full-time individual in an executive position with the Association and that the Board move toward establishing an off-campus arrangement for handling the business affairs of the Association.

It was moved by Hopkin, seconded by Stanton, and carried unanimously that the Association commend Redman for his long and faithful services and express appreciation to Redman and to the University of Kentucky for providing these distinguished services. In deference to the position taken by both the University of Kentucky and Redman which precludes Redman continuing these services, the Board shall initiate a search for a secretary-treasurer who will serve without financial compensation and who will assume this office 1 January 1981.

6. Hopkin moved and it was seconded by Schuh that the report of the Stovall committee be accepted in principle and that the President appoint a committee to delineate the services to be performed by the office of the secretary-treasurer, the Finance Committee, and the American Dairy Science Association (ADSA), and that the committee negotiate the terms of contract with ADSA under which the desired services will be performed and report to the July 1980 meeting of the Executive Board. Motion carried. King appointed Hopkin as chairman, Harl and Stovall as members of the committee.

7. Tweeten moved that the Stovall committee be discharged with thanks. Seconded. Passed.

8. King will prepare items for the Newsletter and a letter to departmental and agency heads informing members of the decision and soliciting expressions of interest in the position of secretary-treasurer.

9. Other business which came before the meeting was as follows:

(*a*) Schuh moved that abstracts of papers presented at the proposed Teaching Workshop be published in the December issue of the *AJAE*.

(*b*) Schuh indicated that the budgetary allowance made for editorial support at the University of Minnesota was insufficient for the last six months of 1980 (transition period). He will request $17,400, as compared to $12,000 budgeted and will request $42,000 for 1981.

(*c*) A concern was expressed on the nature and characteristics of the data being collected by the Registry. No specifics were discussed but it was indicated that this was a concern to be discussed at another Board meeting.

The meeting was adjourned at 12:15 p.m.

Respectfully submitted,
John C. Redman
Secretary-Treasurer

Minutes of the Executive Board Meeting, Urbana, Illinois

The meeting was called to order by President King at 8:30 a.m., 26 July 1980.

Present: Voting Members:
Brown, Coffey, Dennis, Harl, Hopkin, King, Schuh, Stanton, Tweeten
Members ex officio:
Andersen, Koch, Houck, Menzies, Redman, Rhodes
Guests:
Halcrow, Heifner, Martin, Padberg

1. King reviewed the agenda and obtained its approval.

2. King announced the results of the election and congratulated the winners. Schuh was elected as president-elect and Martin and Heifner were elected as directors.

3. Halcrow reported for the Local Arrangements Committee. He indicated that 857 had preregistered and all arrangements were in order. The problem of members attending the meeting without registering was discussed. Various suggestions, including checking name tags at the door, were made to cope with the problem. None were adopted, but President King was instructed to explain why it was important for a member to register and wear the name tag.

4. Redman presented the Minutes of the 27–28 December 1980 Atlanta meeting and of the 10–11 April 1980 Atlanta meeting. Schuh moved the approval of the minutes as revised. Seconded. Passed.

5. Redman distributed copies of the report of the Secretary-Treasurer for 1979 and the report on investment activity for 1979, which will be presented at the annual business session.

6. Padberg reported for the Awards Committee. He suggested some modifications of the awards program for clarification purposes.

Stanton moved that Article V, Section 3, of the bylaws be amended by replacing the statement, "Three awards are offered" to "Three awards are given." Seconded. Passed.

Tweeten moved that Article V, Section 6 of the bylaws be amended to clarify further the nominations by the insertion of "Individual or group efforts may be nominated. In groups, the name and contribution of each person must be identified in the nomination," before the last two sentences in the section. Seconded. Passed.

Hopkin moved that Article V, Section 1, of the bylaws be amended to give two Extension awards—one for an individual and one for a group. Seconded. Passed.

King raised the issue of developing a brochure to announce the awards program by the end of the year. The consensus was to use the *AAEA Newsletter* and "other appropriate" means.

7. King reviewed the events which took place since the 10–11 April 1980 Executive Board meeting concerning the location of the Secretary-Treasurer. The American Dairy Science Association indicated they were not interested in providing the management services for AAEA. King offered to have a representative from AAEA present at the next ADSA board meeting should they desire.

The ADSA board reconsidered the proposal but decided not to take on the task. King then sent a letter to various departments and agencies asking for an expression of interest in the office of Secretary-Treasurer. From this, four responded—Kentucky, American Economic Association, Iowa State, and Mel Janssen with USDA support.

The Kentucky proposal was essentially what was presented at the Atlanta meetings, involved reimbursing the University in the amount of $35,000 for professional time expended, with the University providing adequate office space, fringe benefits, equipment, purchasing advantages, etc. With $20,000 allocated for secretarial and clerical assistance, the total personnel cost would be $55,000, including fringe benefits. The Secretary-Treasurer officially would be assigned full-time duties to the AAEA and the office would provide an uninterrupted flow of services, as it has for the past ten years, for an additional period of five years, including the preparation of a camera-ready copy of the next *Handbook-Directory*, as it did for the 1972 and 1976 editions, and other assigned duties.

The American Economic Association proposal, which was incomplete, provided for maintenance of addressing and membership lists but no accounting, secretarial, or management services. The estimated cost would be $30,000 per year with a one-time cost of $7,000 for processing the information.

The Iowa State proposal involved a total of $43,100 for personnel time and fringe benefits, and would include the secretary-treasurer for one-fourth time and a business manager for one-third time for a three year period. All other activities would be at cost. Nothing was said about the cost of producing a camera-ready copy of the *Handbook-Directory*.

The Janssen proposal was for six years and involved a one-time cost of about $16,000, plus annual personnel cost of about $30,000. This would be for two part-time secretaries and an honorarium for Janssen who is retiring from USDA. The ESCS-USDA was expected to provide space and certain other support, but details were less definite. After the first year, Janssen expected to provide approximately half to three-fourths time. All other activities would be at cost.

Hopkin suggested that the AEA proposal be eliminated and that Janssen and Farrell (ESCS) and Ebert and James (ISU) be present at a convenient time for a few questions. Discussions were delayed until the next day.

8. Rhodes reported as outgoing editor. His report will be given at the general business session. Based on experience, Rhodes noted that too much material had been allocated to the Newsletter and recommended that listing of Ph.D. dissertations be returned to the *AJAE*. The *Journal* also provides a

more permanent record. Stanton moved that the change be made effective in 1981, with a note as to availability of 1979 and 1980 lists. Seconded. Passed.

Houck reported as incoming editor. He announced his Editorial Board and that Martha Luzader would transfer to Minnesota to continue with the *Journal*.

9. King presented the facts on contractual and operational procedures with the University Microfilms. Over the past few years Johnson and Associates, a competing firm, had been contacting AAEA for a portion of the business. Tweeten moved that AAEA not pursue the Johnson and Associates proposals and remain with University Microfilms. Seconded. Passed.

10. Coffey reported for the Finance Committee, presenting a proposed budget and the financial transactions involving the portfolio. The decision on budget composition and approval was delayed until the end of the meeting.

11. Faris and Pittman, of Clemson University, gave a brief summary of the arrangements being planned for the 1981 meeting.

12. Redman reported that liability insurance coverage for AAEA was in effect. Redman presented a proposal received from the same insurance broker for group life insurance for AAEA members. Consensus was that AAEA had no interest in such a program.

13. Redman raised the point that AAEA did not have a positive policy statement concerning discrimination. Harl was requested to draft a suitable resolution to reflect the past and present policy of AAEA. The following was proposed:

Resolution

Whereas, the American Agricultural Economics Association, since the formation of its predecessor organization on or about 1910, has been a professional organization open and equall accessible to all persons without regard to age, race, color, sex, creed, ethnicity, or country of national origin, and,

Whereas, the American Agricultural Economics Association has had a strong commitment to extend membership, committee appointments, honors, awards, elective and appointed offices, and all rights of any type or kind whatsoever to persons affiliated in any manner with the American Agricultural Economics Association without regard to age, race, color, sex, creed, ethnicity, or country of national origin, and,

Whereas, the Executive Board of the American Agricultural Economics Association, acting for the Association, deems it to be advisable, desirable, and in the best tradition of the American Agricultural Economics Association to express formally and unequivocally its commitment to openess to all persons affiliated in any manner with said Association, and, therefore

Be it resolved that the American Agricultural Economics Association, acting through its duly elected Executive Board, does hereby affirm a policy of nondiscrimination to all persons affiliated with the American Agricultural Economics Association on the basis of age, race, color, sex, creed, ethnicity, and country of national origin.

Dated at Urbana, Illinois, this 27th day of July, 1980.

John C. Redman
Secretary-Treasurer
American Agricultural Economics
Association

Harl moved that the statement be accepted and be placed in the AAEA policy manual. Seconded. Passed.

14. Redman reported for the Post-War Literature Review Committee. He reported that 1,685 copies of volume 1 and 1,290 copies of volume 2 had been sold with about one-third of each going to nonmembers. To publish volume 3, the publisher proposed $10,000 subsidy instead of $7,500 for each previous volume and to change the royalty from 35% of sales to nonmembers to 22-½% of all sales. Discount to members would be 30% from the $35 list price.

Stanton moved that AAEA provide a $10,000 subsidy to University of Minnesota Press for volume 3. Seconded. Passed.

Babb, as chairman, will check with Harl regarding the legal aspects of the contract and the committee will develop the procedures for handling and processing orders for members.

15. Schuh reported for the Committee on Fellows Nominations. A concern was expressed about the lack of foreign member nominations, particularly since AAEA has a large foreign membership. Brown moved that the Bylaws be amended to have the committee report one month prior to the winter meeting. Seconded. Passed.

16. Schuh reported as the liaison representative to the National Bureau of Economic Research.

17. Tweeten provided a suggested list of members for the 1980–81 Nominating Committee, with Richard King as chairman, and asked for concurrence. Stanton moved the approval. Seconded. Passed.

18. King announced the dates for future AAEA meetings. They are 26–29 July 1981 at Clemson, South Carolina; 1–4 August 1982 at Logan, Utah; 31 July–3 August 1983 at Lafayette, Indiana; 5–8 August 1984 at Ithaca, New York; and 4–7 August 1985 at Ames, Iowa.

The Allied Social Science Associations, in which AAEA is a participator, will meet 28–30 December 1981 in Washington, D.C.; 28–30 December 1982 in New York; 28–30 December 1983 in San Francisco; 28–30 December 1984 in Dallas; and 28–30 December 1985 in New York.

19. Herr reported for the Resident Instruction Committee. The workshop sponsored by the

AAEA at Southern Illinois University was considered outstanding. Herr recommended that AAEA sponsor a teaching workshop every three years near the time of the AEA annual meeting. Coffey moved the acceptance of the idea. Seconded. Passed.

The bylaws of the Student Section had been out of date and King suggested a revision. The Student Section had some suggested revisions. The two were merged, with King providing a corrected copy. Tweeten moved to amend Article 13 of bylaws to reflect the changes. Seconded. Passed.

20. Meeting recessed at 5:00 p.m., 26 July 1980.

21. Meeting reconvened at 8:35 a.m., 27 July 1980.

22. The discussion on location of Secretary-Treasurer was resumed, with James and Ebert present to give an overview of facilities and cooperation expected from the administration at Iowa State. An account would be set up with ISU, and all receipts and expenses would be processed through that account to obtain audit control. Office would occupy 200 square feet, with an area $5' \times 8'$ for storage. Programming will be at no cost, but computer time will be paid. Questions were fielded.

Janssen and Farrell were present to elaborate on the Janssen proposal. Farrell indicated that the proposal was from Janssen, but ESCS will provide support as much as possible. Space would have to be found, the legality of use of FTS line would have to be determined, support staff cost would be on direct hire or on a reimbursement basis.

Redman indicated he had no further comments on the Kentucky proposal as he felt the Board had a complete understanding of the proposal which for the next five years would continue the uninterrupted flow of services as provided for over ten years, though perhaps on an increased level. The only major difference was that Kentucky was asking for $35,000 for partial reimbursement of professional time and services, and Redman officially would devote full time to AAEA activities. The expiration of the five-year period would coincide with Redman's planned retirement from the University.

The Board went into executive session.

Minutes of the Executive Session of the Board

The Board was convened in Executive Session at 10:05 a.m., 27 July 1980, by President King. Stanton was appointed secretary during this meeting. Harl excused himself from the meeting on the basis of potential conflict of interest because Iowa State University had submitted a proposal for Board consideration.

The Board members then discussed in detail the proposals presented, budget considerations associated with them, and the respective abilities of the institutions involved to process association data and accounts. A secret ballot was taken with each Board member listing his first preference for location of the office of secretary-treasurer and the business office of AAEA. The vote was eight in favor of locating at Iowa State University.

It was moved by Hopkin and seconded by Coffey that on the basis of the unanimous vote of preference obtained in secret ballot with all members of the Board present, excepting Harl who absented himself from both the discussion and final vote, the AAEA accept the proposal of Iowa State University to provide the services of the secretary-treasurer and the business office of the Association, to take effect not later than 1 January 1981, and that arrangements to effect this transfer be initiated immediately for the orderly and expeditious movement of the functions of the office and properties thereof. This motion was carried unanimously. Harl returned to participate in the balance of the meeting.

It was moved by Stanton, seconded by Schuh, that Sydney James be appointed secretary-treasurer of the AAEA for a term of one year, in accordance with Article VI, Section 2 of the Constitution, such appointment to be effective 1 January, 1981; and in accordance with the provisions of Article VI, Section 4 of the Bylaws, the Executive Board by this action confirms a commitment of three years to the appointment of Sydney James to the office of secretary-treasurer, subject to a performance evaluation each year preceding reappointment. The motion was carried unanimously with Harl abstaining from the vote.

It was moved by Schuh, seconded by Dennis that Sydney James, Secretary-Treasurer designate of the Association, be given the authority to create a business office for the Association at Iowa State University and to retain services of such individuals as shall be reasonably necessary to implement the establishment of the business office within the resource constraints of the Iowa State University proposal submitted and approved by the Executive Board on 27 July 1980. The motion was carried unanimously, with Harl abstaining from the vote.

It was moved by Coffey, seconded by Brown that a contingency fund of $15,000 be established from Association funds for the purpose of paying actual costs of the move of property and inventory of the Association, necessary travel costs, and other actual fees and costs incurred in the transfer of the office of secretary-treasurer from the University of Kentucky to Iowa State University and for the costs of services needed prior to 1 January 1981 to make operational the office of Secretary-Treasurer, including but not limited to reimbursement for wages, salaries, employee benefits, and other costs associated with the employment of necessary persons. The sum of $15,000 is to be deposited on account with the Business Office of Iowa State University, with amounts remaining to revert to the general funds of the Association after payment of all costs authorized in this motion. The motion was carried unanimously with Harl abstaining from the vote.

It was further moved by Schuh, seconded by Coffey that a three-person special committee be

created to formulate and implement plans for transferring the office of Secretary-Treasurer of the Association from the University of Kentucky to Iowa State University, with the appointment of members by the President of the Association. The motion was carried unanimously, Harl abstaining. Members appointed to this committee are John Hopkin, Tom Brown, and Earl Swanson.

It was moved by Schuh and seconded by Stanton that a Resolution of Appreciation and Special Commendation to John Redman for meritorious service to the Association be drafted and presented at the business meeting Tuesday morning, 29 July. This motion was carried unanimously.

The Executive Session was concluded at 12:15 p.m.

23. The Board resumed in a regular session with Mitchell reporting on the Selected Paper sessions. He indicated that 178 papers were received, from which 128 were selected, 28 more than last year.

24. Badger reported for the AAEA Literature Retrieval Committee. The committee recommended that (*a*) AAEA renew the cooperative agreement between AAEA and ESCS for fiscal year 1 October 1980–30 September 1981 and provide $19,000 to ESCS for operation of the literature retrieval service through the AAEDC; (*b*) an intensive public relations effort be undertaken to encourage the members to use the system; (*c*) the committee analyze the deficiencies in the system and make suggestions for correction; (*d*) the committee contact several major vendors of literature retrieval information to delineate and analyze alternatives; (*e*) AAEDC and ESCS explore the feasibility of contractor assistance to catch up in inputting literature into the file; (*f*) a Newsletter be initiated to improve the flow of services; and (*g*) hold a workshop to train reference librarians, computer specialists and library personnel to use the service.

Schuh moved the report be accepted and the committee be commended. Seconded. Passed.

Hopkin moved that AAEA allocate $19,000 as requested and to renew the agreement. Seconded. Passed.

25. Farrell reported for the task force on Operational Data Base for AAEA Activities. The report is rather comprehensive, listed the AAEA management and information requirements, information lending itself to automation, and discussed the feasibility of automation. Hopkin moved the acceptance of the report. Seconded. Passed.

26. Bromley reported for the Professional Activities Committee. He reported that the committee had recommended that AAEA sponsor (*a*) a teaching workshop with Herr as the organizer; (*b*) a symposium in cooperation with the American Meteorological Association on the value of weather information, with Eisgruber on the planning committee; and (*c*) a symposium in cooperation with the American Society of Agricultural Engineers on national energy issues, with Otto Doering on the planning committee.

The committee recommended that AAEA express an interest in becoming affiliated with a Federation of Scientific Agricultural Societies (FSAS) which would consist of the presidents of about forty professional societies. Stanton moved that AAEA become affiliated and allocate $400 for the membership fee. Seconded. Passed.

The committee also recommended that AAEA cooperate with seven or eight other societies in organizing a 1981 conference on research priorities in soil and water conservation and productivity. Hopkin moved that AAEA cosponsor the workshop with no financial support. Seconded. Passed.

27. Crowder reported for the Industry Affairs Committee. The committee recommended that an award for excellence in research relating to current business problems be established. It would be funded by the Industry Affairs Committee or private sources. Schuh moved that the report be accepted. Seconded. Passed.

28. Gardner reported on the Committee of Professional Associations on Federal Statistics (COPAFS), the Economics Statistics committee, and the Census Advisory Committee on Agricultural Statistics. Schuh moved the acceptance of the report. Seconded. Passed.

29. Mathia reported for the Membership Committee. A question was raised whether or not membership recruiters were violating the privacy of individuals regarding payment of dues. Harl moved that the President of the AAEA be authorized to commission members of the Association as local membership representatives and to make available to said individuals lists of members and nonmembers of the Association as needed in fulfillment of membership recruitment efforts. Seconded. Passed.

30. Extension Affairs Committee circulated a report indicating that it was in process of assessing its objectives and role in the profession. It was reported that a workshop was being explored. Tweeten moved that AAEA enthusiastically endorse and encourage the Extension Affairs Committee to develop the idea of a workshop and urge it to work with the Professional Activities Committee in preparing a proposal. Seconded. Passed.

31. King presented a report for the International Committee prepared by Nobe. A request was made to convert the committee to the status of a standing committee. No action was taken. Hopkin moved the acceptance of the report. Seconded. Passed.

32. King presented a report of the Professional Registries Committee prepared by Allan Johnson. The grant from Department of Labor was extended to 30 June 1981, with no additional funding. Hopkin moved acceptance of the report. Seconded. Passed.

33. Harl presented a letter from Lundeen concerning the status of women in AAEA. The Board considered various approaches to the problems of minorities. No action was taken, but the incoming President may wish to explore the concern further.

34. Anderson raised the possibility of closer cooperation with the regional associations with AAEA collecting and remitting dues. Coffey moved that the secretary-treasurer of AAEA be authorized

to cooperate with the regional associations by accepting payments of dues for membership in these associations and remitting the payment to them. Seconded. Passed.

35. King discussed the report circulated by CAST indicating the number of agricultural economists as AAEA representatives on various task forces. It was noted that AAEA will continue to assist in identifying agricultural economists who may have an interest in CAST activities as individuals but not as AAEA representatives.

36. Coffey presented the budget for 1981 incorporating the financial commitments made during the meeting. It showed a deficit of $12,728. Stanton moved the acceptance of the budget. Seconded. Passed.

37. It was suggested that the Board meet 9–11 December in St. Louis, to develop a joint program for 1981 with the Southern Agricultural Economics Association.

38. Board adjourned at 5:15 p.m.

Respectfully submitted,
John C. Redman
Secretary-Treasurer

Minutes of the Annual Business Meeting, Urbana, Illinois

The 69th annual meeting was called to order by President R. A. King on 29 July 1980, at 8:15 a.m.

1. King presented for approval the minutes of the annual business meeting held at Pullman, Washington, 31 July 1979, as published in the "Proceedings" issue of the *Journal*. Motion was duly made to approve the minutes. Seconded. Passed.

2. King announced the results of the election of officers. G. Edward Schuh was elected as President-Elect, and William E. Martin and Richard G. Heifner were elected as Directors.

3. King recognized the directors and ex-officio members of the Executive Board.

4. King gave his presidential report. The report will be published in the "Proceedings" issue of the *Journal*.

5. Redman presented the secretary-treasurer's report. Motion was made to accept the report. Seconded. Passed. The report will be published in the "Proceedings" issue of the *Journal*.

6. King presented the report of the certified public accountant on the financial condition of AAEA and indicated that a copy would be on file for anyone desiring to examine it. Motion was made to accept the report. Seconded. Passed.

7. Coffey reported for informational purposes some budgetary items for the 1981 budget, which will show a deficit of $12,718.

8. Rhodes reported as editor of the *Journal*. His report was accepted and will be published in the "Proceedings" issue.

9. No old business was noted.

10. Under new business, King recognized G. Edward Schuh for a resolution of appreciation and special commendation to John Redman for meritorious serivce as secretary-treasurer of AAEA since January 1970. Motion was made to accept the resolution. Seconded. Passed with a standing ovation. The resolution will be published in the "Proceedings" issue of the *Journal*.

Motion was made from the floor that AAEA Executive Board elect John Redman as a Fellow of AAEA. Seconded. After it was pointed out that the bylaws stated that Fellows Election Committee did the election, the motion was changed to the following: Move that the Executive Board nominate or submit and support the name of John Redman to the Fellows Election Committee to be elected as a Fellow. Seconded. Passed unanimously.

11. King announced that the next annual meeting will be on the campus of Clemson University on 26–29 July 1981.

12. King recognized Schuh again for Resolutions thanking the host, the University of Illinois, for a job well done; University of Missouri and especially editor V. James Rhodes, associate editor Stanley Johnson, assistant editor Martha Luzader, and Oregon State University, especially book review editor Herbert Stoevener for support and outstanding performance for the past three years; and the University of Kentucky for providing a home for AAEA for the past ten years. Motion was made to accept the Resolutions. Seconded. Passed. The Resolutions will be published in the "Proceedings" issue of the *Journal*.

13. King thanked the retiring members of the Executive Board—Stanton, Coffey, and Schuh—for their assistance and dedicated work.

14. King recognized and turned the chair over to Luther Tweeten as the new president. Tweeten announced the names of the Nominating Committee.

15. Meeting adjourned at 9:20 a.m.

Respectfully submitted,
John C. Redman
Secretary-Treasurer

Resolutions

Wishing to acknowledge the support given to the *American Journal of Agricultural Economics* during the past three years,

Be it resolved that the American Agricultural Economics Association expresses its appreciation to the Department of Agricultural Economics of the University of Missouri at Columbia for the support given the *American Journal of Agricultural Economics*. The special thanks of the Association are due the Editor, V. James Rhodes, the Associate Editor, Stanley Johnson, and the Assistant Editor, Martha Luzader, for their outstanding services. In addition, the Association wishes to express its deep

appreciation to Herb Stoevener of Oregon State University for his services as Book Review Editor.

Be it further resolved that a copy of this Resolution be sent to the appropriate administrative officials of the University of Missouri and Oregon State University.

Passed unanimously at the University of Illinois, Urbana, Illinois.

We wish to acknowledge the warm and cordial hospitality shown the members of the American Agricultural Economics Association, their families and guests, on the occasion of the annual meeting held at the University of Illinois on 27–30 July 1980. *Therefore,*

Be it resolved that the American Agricultural Economics Association expresses its sincere gratitude to President Stanley O. Ikenberry, to Daniel I. Padberg, Head of the Department of Agricultural Economics and his faculty, staff, and students and their families, and to Carole Holden, Conference Coordinator of the staff of the Conferences and Institutes division for their hospitality.

All of these, under the able and devoted leadership of Harold G. Halcrow, chairman of the Local Arrangements Committee, as constituted and reported on pages 45–47 of the program, have served us effectively and graciously.

Be it further resolved that a copy of this Resolution be sent to President Stanley O. Ikenberry, Daniel I. Padberg, Carole Holden, Harold G. Halcrow, and to each of the various committees and to others at the University of Illinois as appropriate.

Passed unanimously at the University of Illinois, Urbana, Illinois.

The University of Kentucky has been the home of the Secretary-Treasurer's office of the American Agricultural Economics Association for ten years. It has provided to the Association the services of one of its most able agricultural economists, Dr. John Redman. It has provided office space and general support for the Secretary-Treasurer and its staff.

In light of the above, *Be it hereby resolved* that the American Agricultural Economics Association expresses its deepest appreciation to the Department of Agricultural Economics of the University of Kentucky and its staff for the support of this important office and function of the Association.

Be it further resolved that a copy of this Resolution be sent to the appropriate administrative officials of the University of Kentucky.

Passed unanimously at the University of Illinois, Urbana, Illinois.

John C. Redman has been Secretary-Treasurer of the American Agricultural Economics Association for ten years. During that period he has served the Association and its members extremely well. To enumerate all the many things John has done would be difficult, if not impossible. But, those of you who know him, or are familiar with his activities, know that there is no request that is too small for him to attend to; you know the many hours of dedicated service he has given to the Association—in keeping up mailing lists, in keeping checks deposited and checks emitted, in preparing all the many certificates for the award ceremony each year, and in attending to numerous other aspects of the Association's business; and you know the inimitable style and grace with which he has done all of these things.

One of John Redman's important contributions over the years has been to the Executive Board of the Association. John has served as the institutional memory of the Board as outgoing members phased out and new members came on stream. He has oriented new members of the Board and Officers of the Association and saved many of us from missteps and even possibly major errors. His penchant for detail has been a help to us all. His penchant for orderliness has saved Board members countless hours, as he was able to retrieve bits and pieces of vital information from his well-organized and portable files. John has a rich knowledge of names and of people working in the profession, and has brought this knowledge to the meetings of the Board. John has a sensitivity for history, and in particular for what the Association and former Board members have done. All of these things John has combined with judgment and insight to contribute to the deliberations of the Board with ideas, suggestion and recommendations.

But John's contributions to the Association go much beyond his efforts on behalf of the ever-changing Executive Board. John has had a commitment to high standards for the Association. It has been largely due to John's efforts that the Award Ceremony each year comes off without a hitch. When statements for the presentation of the prestigious Fellows awards were not available, for example, John would sit up all hours of the night preparing them.

John also contributed importantly to the design of the present organizational structure of the Association. John's frugality has been both a bane and a blessing to members of the Board and incumbent presidents, but his honesty and integrity have set a standard for both the Board and members of the Association. John has saved the Association substantial expense through his ingenious use of resources, through the care with which he has searched out savings on things we needed to purchase, and through the inputs of his own personal time to activities of the Association. In the case of the San Diego meetings of a few years back, to cite only one example, John served as essentially a one-man local arrangements committee. Few people recognized this at the time.

Perhaps as important as any of these things that John has done, he has done it all with a cheerful and happy mien, and with style and good grace.

In light of the above, *be it hereby resolved* that the American Agricultural Economics Association

expresses its deepest appreciation to John C. Redman for the many hours of faithful, dedicated, and effective service he has given to the Association. *Be it further resolved* that a copy of this Resolution be sent to the appropriate administrative officials of the University of Kentucky.

In closing, we would like to take note of the fact that John Redman was a well-recognized and distinguished member of the profession at the time he took on the demanding job of Secretary-Treasurer of the Association. John, we all wish you well as you return to being a productive member of the profession in this next phase of your career. And, we look forward to your continued contributions to the activities of the Association.

Passed unanimously with a prolonged standing ovation at the University of Illinois, Urbana, Illinois.

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